The
GEOGRAPHICAL JOURNAL

Vol LXXXV No 4 R.G.S. *April 1935*

NANDA DEVI AND THE GANGES WATERSHED: *A paper read at the Evening Meeting of the Society on 4 February 1935, by*

ERIC SHIPTON

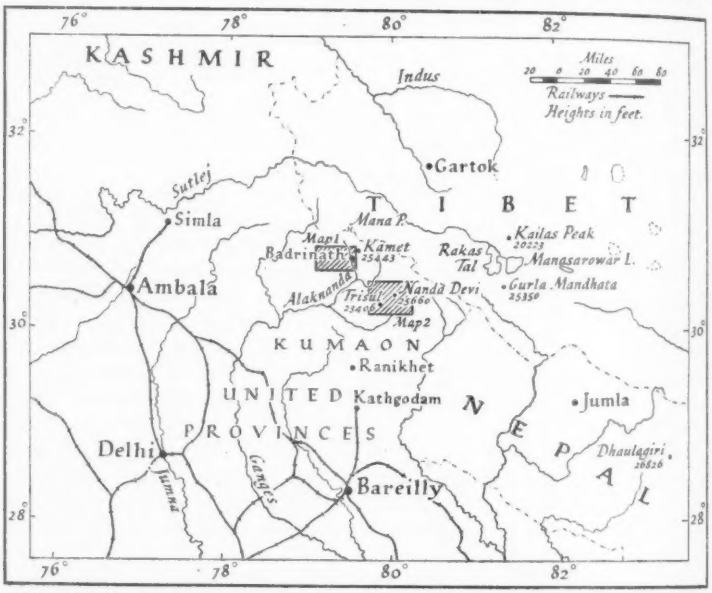
THE section of the Himalaya which gives birth to the river Ganges is perhaps the most visited portion of that vast range. A hundred thousand pilgrims throng each year to the sacred Hindu shrines of Badrinath, Kedarnath, and Gangotri, which are situated near the three main sources of the Holy River. A mass of fascinating legends and semi-mythical stories centre round these parts. Of these Hindu literature is full. This being so, it is curious that to this day the geography of the peaks, glaciers, and less accessible valleys of these parts is very little known, and vast tracts of country still remain unmapped and unexplored.

It is difficult to account fully for this fact. The country lies almost entirely in British territory, and no political difficulties have to be overcome before an expedition is allowed to visit it. Moreover the transport of supplies and equipment over the foot-hills to a suitable base is a simple matter, the organization of which does not require any previous knowledge of the country. There is only one obvious reason why there still remains so much minor exploration to be done in those parts, and that is the extraordinary character of the mountains and valleys themselves. These certainly present quite unusual difficulties of access. When I decided to take a small expedition to the Garhwal Himalaya this year I had plenty of choice and decided after due consideration to attempt to make a thorough exploration of the range which forms the watershed between the Badrinath, Kedarnath, and Gangotri valleys.

No one attempting mountain exploration in the Himalaya can afford to miss an opportunity of discussing his plans with Dr. Longstaff. When he gave me that opportunity therefore I accepted it with avidity. He was kind enough to give me two days of his time in spite of the fact that he was himself leaving for the Arctic in a short time. As a result of those two days, the Badri-Kedar watershed became a thing of secondary importance, and I had determined to make an attempt to force an entrance into the hitherto inviolate sanctuary of the Nanda Devi basin. I am glad that Dr. Longstaff is one of the very few who can fully appreciate the debt I owe him for this change of programme. I am

deeply indebted also to Mr. Hugh Ruttledge for much valuable advice and encouragement.

Regarding Nanda Devi I need not say much. It is the highest mountain entirely in British territory, and yet, though several expeditions had tried to reach it, no one had so much as penetrated to the glaciers which rise at the feet of the great mountain. The main difficulty lay in the fact that the peak is encircled by a vast amphitheatre of mountains which, I believe, is unique. It is hard for any one who has not studied the phenomenon at close quarters to form an adequate conception of this gigantic rampart, in places over 22,000 feet high, enclosing a bit of country, itself not above the limits of dwarf trees,



The Garhwal Himalaya, showing areas of Mr. Shipton's explorations

out of whose centre there rises a stupendous peak, 25,600 feet. The interior of this circle had never been visited and the foot of Nanda Devi never reached.

The water rising from the glacier system of this basin flows to the west through a narrow gorge, the Rishi Nala, which forms the one break in the huge amphitheatre. One would naturally suppose that the best line of attack would lie here, but the extraordinary difficulties of the gorge are such that, since Dr. Longstaff visited it in 1907, all aspirants to reach the foot of Nanda Devi have attacked the mighty walls of the basin.

As early as 1883 that redoubtable Himalayan explorer, W. W. Graham, accompanied by two Alpine guides, Emile Boss and Ulrich Kauffmann, made two determined attempts to force a route up the Rishi Ganga. The first was frustrated at the very mouth of the gorge by sheer walls of rock. Later, he contrived to avoid the lower part of the gorge by making a big detour to the

north, and, after overcoming immense difficulties, he contrived to force a re-entrance into the valley higher up. Here he was deserted by his porters, local men who believed the valley to be the abode of demons. Undaunted, he and his guides struggled on alone, but were at last forced to admit defeat by the sheer difficulties of the gorge.

Others tried later with less success. But it was not until 1905 that Dr. Longstaff devoted his indefatigable energies to the problem of gaining access to the Nanda Devi basin. In that year he was accompanied by the two Brocherels of Courmayeur. They approached the mountain from the head of the Milam Valley, which bounds the Nanda Devi group on the east, and ascended the Panchu Glacier, crossing a new snow pass at its head. This brought them on to the Lwanl Glacier running parallel with the Panchu, and not into the Nanda Devi basin as their map had led them to expect. They descended to the main valley for supplies, and shortly afterwards re-ascended the Lwanl Glacier. After three days' climbing they gained the Kumaon–Garhwal water parting, which forms at this place a part of the rim of the Nanda Devi basin. From here for the first time in history they looked down on to the glaciers at the southern foot of the great mountain. A descent on the other side of the ridge was found to be impracticable.

Further exploration of the group was made in 1907 by Dr. Longstaff, General Bruce, Mr. A. L. Mumm, and three Alpine guides. Their first objective was the Rishi Valley. Examination of the lower gorge decided them to attempt Graham's route, the first part of which was known to the Tolma and Lata shepherds. But they were too early in the year and found too much snow to allow them to make a passage of the Durashi pass. The party moved round to the Bagini Glacier, and after several days of difficult mountaineering, crossed a 20,000-foot pass at its head. Again they were disappointed. They had hoped that the pass would lead them onto a glacier flowing down into the Nanda Devi basin; but on descending the glacier they found themselves in the Rishi Nala at a point below that which Graham had reached in 1883. It was soon after this that Dr. Longstaff made his famous ascent of Trisul.

Afterwards he visited the mouth of the upper gorge. I should like it to be understood that no serious attempt was made by the party to force a route up this upper gorge and that Dr. Longstaff did not have the time or food enough to do so. Several attempts to get into the basin were made since that date, notably those of Mr. Hugh Ruttledge, who, in 1932, tried with the guide Emile Rey to cross from Maiktoli, a gap at the head of the Sonadhunga valley on the south.

It is a mountaineering axiom that each successive attempt upon a problem makes that problem easier to solve. Few great mountains were climbed and few passes crossed at the first attempt. The man who eventually reaches the summit of Mount Everest will have done so, not by his own efforts alone, but over the shoulders of the pioneers—Mallory, Norton, Somervell—without whose hard-won experience he would have stood no chance. It should be clearly understood therefore that what measure of success we have had this year we owe primarily to those who had gone before us.

It was our plan to attempt once more to get up the Rishi Nala. Our first project was to get a month's provisions to the junction of the Rhamani stream

with the Rishi, which was about the farthest point previously reached in this direction. From here Dr. Longstaff advised us to attempt to force a way across the cliffs of the southern side of the gorge.

It was necessary to conduct the expedition with the strictest regard to economy. Careful accounts were kept of expenses both in England and India. The total cost worked out at £287. We were in the mountains for just under five months. On Dr. Longstaff's advice the party was a small one, and I was extremely lucky in having four ideal companions. They were H. W. Tilman, with whom I had climbed a good deal in East and Central Africa; Angtharkay, who was one of the two Sherpas on Mount Everest last year who sat through that three-day blizzard at Camp 5 and then volunteered to carry to Camp 6; Passang Bhotia was another Camp 6 man; and lastly Kusang Nangir, a man of extraordinary toughness and imperturbability.

The party reached Ranikhet on May 9. We engaged twelve Dotial porters for the march across the Kuari pass and left Ranikhet early on the morning of the 11th, reaching Gwaldam the same night. For nine delightful days we wandered through the lovely foot-hills of the range, over passes clothed with pine, oak, and rhododendron woods. Here and there we obtained superb views of the peaks we were making for. An early morning view from the Kuari pass showed us that wonderful panorama in its most inspiring setting.

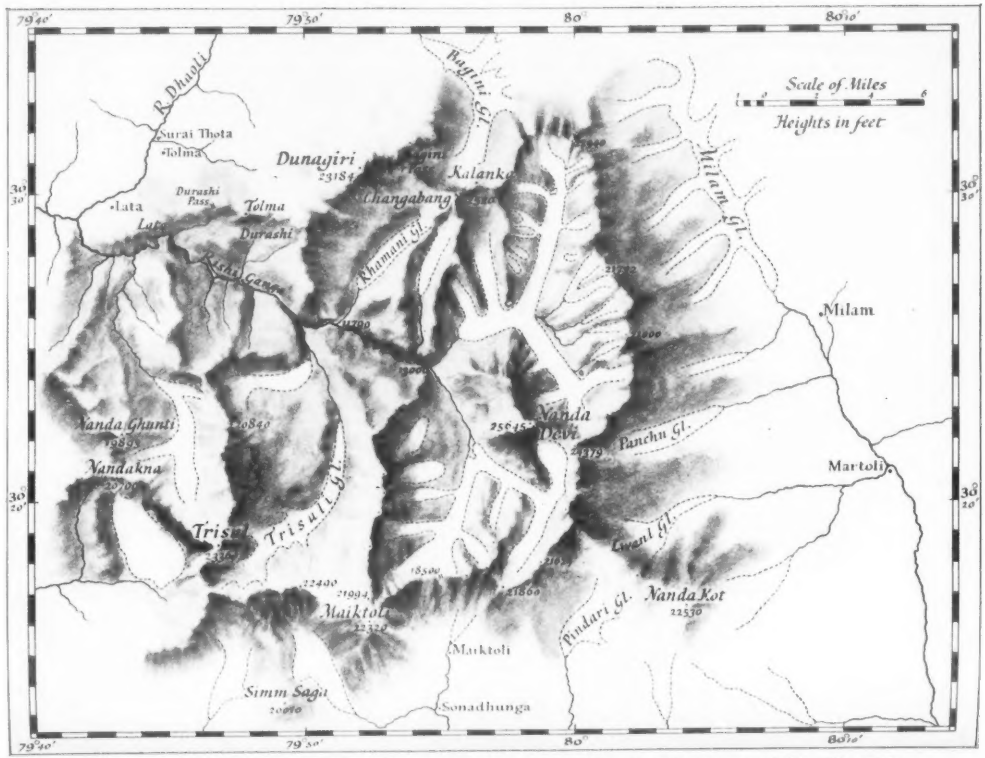
We reached Joshimath on the 19th and spent a busy day in the arrangement of our bandobast. Eleven of the Dotials requested to be allowed to remain with us as long as we required porters. With them we left Joshimath on May 21. On May 22 from Tapoban, in the Dhaoli valley, three of the party ascended the little Lata peak so as to get a view up the Rishi Ganga and to get started with our plane-table, descending that evening to Surai Tota.

The following morning we collected supplies of food at Surai Tota and engaged the services of eight more local people to help with the transport and to supply local knowledge for at least the first part of the route. We left the same morning (May 23). It was early in the season and there was a great deal of snow on the passes which constitute Graham's "back-door" entrance into the middle section of the Rishi Nala. These passes are used in summer by the Lata and Tolma shepherds of the Dhaoli valley, who take their sheep across them to a little alp known as Durashi.

The Surai Tota men deserted us after the first day. This produced a serious crisis which threatened to destroy at the very outset our plans for the exploration of the Rishi Ganga. For, in these parts, a very short time remains between the melting of the winter snows on the lower passes and the breaking of the monsoon. However the Dotials shouldered enormous loads and followed us with wonderful determination and loyalty.

Being now without the help of local knowledge we floundered for nearly two days through snow waist-deep before we could get across the passes to Durashi. Part of the route lies across some cliffs at an altitude of 14,700 feet. From here we could look down an 8000-foot precipice into what must be one of the most fantastic gorges in the world. It has never yet been penetrated by any human being and it is believed by the local people to be the abode of demons: a superstition we were quite ready to share. The river, only just visible in the depths below us, sent up a roar like that of Niagara.

Nanda Ghunti from above the Wan



The Nanda Devi basin, from a plane-table survey by E. E. Shipton and H. W. Tilman

In m
again g
Tota m
steep a
reachin
It was
remark
vital co
three c
We
junctio
southe
reache
north.
base.
starte
Our
Rishi
camp
one o
agree
conce
not lo
were.
culmi
We
canyo
into
along
relen
sides
form
along
below
then
Th
rout
in g
so.
plea
Late
legs
swe
it w
pair
han
On
on

In making our way along the northern flanks of the Rishi Valley we were again greatly handicapped by the lack of local knowledge, which the Surai Tota men would in all probability have provided. The flanks of the valley are steep and cut into innumerable ravine-like gulleys. We were constantly reaching some cut-off which could be avoided only by making a big detour. It was terribly hard work for the Dotials, who carried their huge loads with remarkable skill and courage. Also we kept them at it all day, as food was a vital consideration and each extra day we spent in getting to our base meant three days less for our work beyond.

We kept to the northern side of the valley until a mile or so beyond the junction of the Trisuli stream. Then we bridged the river and crossed to the southern bank. Late in the evening of May 28, in a heavy snowstorm, we reached the point where the Rhamani stream flows into the Rishi from the north. Here under the overhanging walls of the canyon we established our base. The Dotials were discharged and early on the following morning they started down the valley, leaving us to our own resources.

Our next task was to find a route through the unknown upper part of the Rishi Nala into the Nanda Devi basin, now barely 4 miles distant. Our base camp was on the southern shore of the river, at a point where the gorge forms one of its narrowest bottle-necks. We made our height 11,800 feet, which agreed well with Dr. Longstaff's reckoning. Dr. Longstaff had advised us to concentrate our search for a route mainly on the southern side. Indeed it was not long before we saw how utterly impregnable the cliffs of the northern side were. They rise straight out of the river-bed, seemingly without a break, and culminate in peaks of 20,000 odd feet.

We started at once upon our hunt for a route along the southern wall of the canyon. It was absorbing work and we spent our time being led alternately into a state, first of wild excitement, then of exasperation, as we traversed along some narrow ledge to some impassable cut-off. Looking at those grim, relentless cliffs, the chances of a continuous route along their precipitous sides seemed very slender indeed, and it was only due to a series of freak rock formations that, after an exhaustive search, we succeeded in effecting a passage along a series of delicate traverses over giddy drops to the river, 1000 feet below. Several sections of the route had to be roped up. Food and kit were then carried up in relays.

The last half-mile of the gorge looked so hopeless that we decided to try a route along the river-bed itself. When the river was low we actually succeeded in getting through that way, though we had to ford the stream six times to do so. We found it impossible however to get our loads up, and after some unpleasant adventures were obliged to abandon the route and search for another. Later we came to regard these river crossings as most serious obstacles. One's legs were numbed by the icy water and lashed and cut by innumerable stones swept down by the river. We found that when the water reached our waists it was impossible to resist the current. The usual procedure was for the first pair to cross holding hands for mutual support, then the others would follow hanging on to a rope stretched across the river.

Careful search revealed a continuation of our route 2000 feet above the river on the southern side, and on June 6, after nine days' work (from our base in

The Nanda Devi basin, from a plane-table survey by E. E. Shipton and H. W. Tilman

the Rishi Valley) we established an advance base (13,000 feet) in the Nanda Devi basin, with sufficient food to last our party of five for three weeks. We had left food dumps at intervals down the gorge.

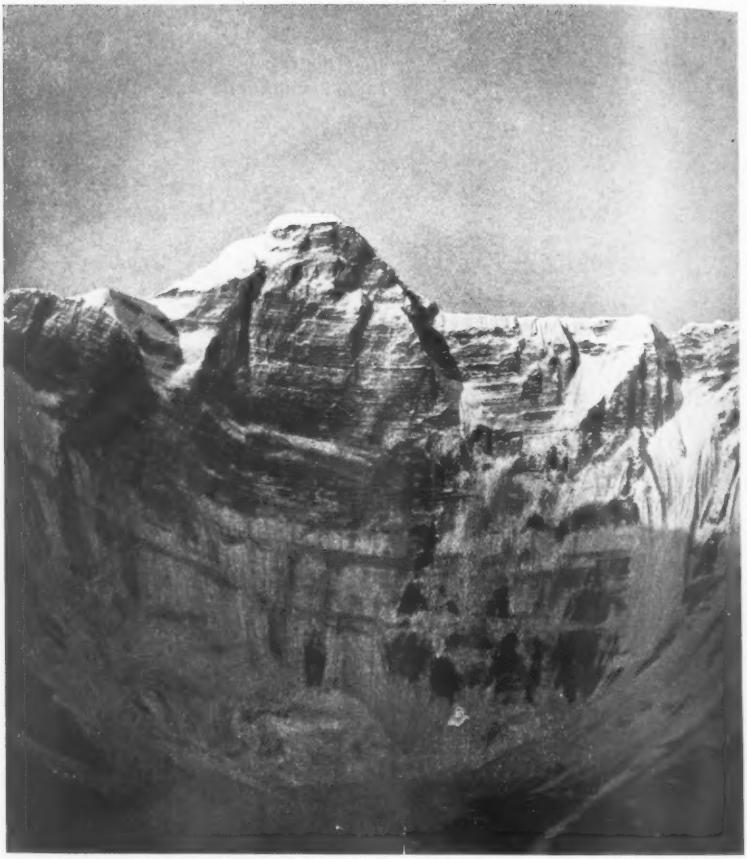
The country we were now in is an extraordinary freak of nature, and is, to the best of my knowledge, unique. As I have said, it is enclosed by a gigantic rampart of scores of peaks between 20,000 and 23,000 feet in height. The only breach in this amphitheatre is the gorge we had just come up. In the centre of the basin rises one of the most colossal masses of rock in the world, the majestic peak of Nanda Devi, whose sides are so exceedingly steep that even the plastic Himalayan ice can find little room to cling. North and south of the peak flow two great glaciers, the streams issuing from which unite some miles below the snouts of their respective glaciers and form the Rishi Ganga, which later adds its water to the Ganges. A large number of subsidiary glaciers flow down from the peaks of the amphitheatre to the main glaciers.

With a bare three weeks at our disposal we decided to concentrate on the exploration of the northern section of the basin, and to return if possible after the monsoon to investigate the country to the south of Nanda Devi. The interior of the basin was very different from what we had expected. I had pictured deep, steep-sided valleys entirely filled with moraine-covered glacier. Actually we found the country to be wonderfully open. There were extensive areas of rich pasturage, gay with wild flowers, and lakes on whose deep blue and green surfaces were reflected the icy crests of the great peaks. We found too a considerable variety of birds, and large herds of tar and bharhal, which were so tame and regarded these strange new visitors into their country with such curiosity that I was very glad not to have brought a rifle with which to supply ourselves with food.

In consequence of the open country we found travel to be much easier than is usual in the glacier regions of the Himalaya. This was a welcome change after our recent experiences in the Rishi Nala. Nevertheless we had an exceedingly busy time and none to waste. The first two days in the basin were spent in ascending various points above the snout of the main north glacier, which commanded views suitable for our plane-tabling. We soon found how exceedingly difficult it was to identify any of the triangulated peaks on our graticule sheet with any degree of certainty. Over-confidence in this respect led us into a lot of trouble at first; and it was some time before we came to know which points we could trust, and to build from them a network of suitable fixed points inside the basin.

On June 9 we reached a beautiful little lake, about 8 acres in extent, near the junction of the three biggest glaciers of the northern section. The main north glacier takes a sharp southward bend hereabouts, and is joined by a very large glacier coming in from the north. This came to be known as the Great North Glacier. Half a mile farther south another ice-stream comes in from the combe formed by the ridges of the two majestic peaks of the G.T.S. A.21: Changabang and Kalanka of Longstaff's map. Tilman suggested the name Changalanka for this glacier and seemed disappointed when I expressed my doubt if it would be accepted by the authorities. The difficulty however was overcome when we subsequently discovered another big ice-stream flowing from the north-east face of Kalanka. A camp on the farther side of the Great

The north face of the main peak of Nanda Devi



North face of eastern peak of Nanda Devi, 8000 feet above the glacier

The twin peaks of Nanda Devi from the ice-plateau at the head of the Great North Glacier

North Glacier served us as a main base for the rest of our stay in the northern section. For convenience we called it Junction Camp.

Our first task was to investigate the valleys coming in from the eastern rim of the basin. For the sake of convenience we numbered these, starting from the south. It was our plan to put light camps in each of the valleys in turn; these were to be occupied by Tilman and me, while the Sherpas worked between the lower camps and the higher. A remarkably broad strip of grassland ran outside the well-defined lateral moraine of the main glacier; this provided us with a high-road almost up to the head of the main valley.

From our camp in lateral valley No. 1 we were able to see to its fullest advantage the colossal northern face of the twin peaks of Nanda Devi. From the summit ridge it falls in one unbroken sweep to the glacier which lies at its foot. For hours on end, in every combination of light and shadow, we were able to gaze upon that cirque, but I never got tired of doing so or lost my early amazement at the sight.

Above this camp, at an altitude of about 18,000 feet, I came upon a bharhal. It was about 25 yards away and we stood and looked at one another for some minutes before the animal moved slowly away. Unfortunately I had not got my camera with me at the time. A taste for mountaineering seems to be the only explanation for these creatures visiting such altitudes.

We succeeded in reaching a 20,000-foot col on the eastern rim above Glacier No. 2, and from it climbed a peak of about 21,000 feet (June 11). From these points we got views to the east over an extraordinary tangle of peaks in the Milam district.

Within half an hour of returning to our high camp after climbing the peak I was stricken by a fever. It started by a violent attack of shivering and an acute pain in the top of the right leg. It lasted for about thirty-six hours, was accompanied by some mild delirium, and left me as suddenly as it had come. Nearly a week later Tilman was confined to his bed by a complaint exhibiting almost exactly similar symptoms.

We reached another point on the eastern rim above Glacier No. 3, also above 20,000 feet. We were anxious to find a practicable route out of the basin in this direction but from the points we reached we could see no way down on the other side. Throughout the whole season we struck vile snow conditions. This was one of the most serious obstacles we had to contend with.

On June 16 we started up the Great North Valley. Travel here was considerably more difficult. The glacier is a good deal longer than the main one above the junction and has a number of considerable tributaries coming in from the ridges of Kalanka and from the peaks of the "rim." It rises from an extensive snow-field between G.T.S. peaks 113 and 110. In bad weather we pushed a camp high up in this direction, and spent some days investigating the complexities of this great ice plateau. We reached a col of some 20,500 feet between the two peaks. From here we looked straight down on to the moraine-covered Bagini Glacier, a sheer drop of nearly 5000 feet. We also made two attempts (June 19/20) to climb peak 110, which is nearly 23,000 feet high. On both occasions we failed on account of dangerous snow conditions. We were anxious to get up it, primarily in order to get a more comprehensive

idea of the complex topography of the country to the north. Our time in this fascinating valley was all too short.

As we descended (June 22) the glacier once more we found that there was an alarming increase in the rate of melting of the ice. The surface streams were enormously swollen and from deep down in the bowels of the glacier there came an ominous roar. Before we could reach the southern bank of the Rishi we would have to ford both the northern and the southern streams and we were in some danger of being cut off.

On June 24 the monsoon broke. This surprised us as we had not expected it for at least another two weeks. On the 25th we began our retreat to the Rishi Ganga. Our fears regarding the state of the rivers were well founded and we had a very tough job to cross the one below the snout of the Main North Glacier. Lower down we found that the Rishi was in flood. We were forced to cross it by a natural rock bridge below our base camp and to climb for 2000 feet up the Rhamani gorge before we could find a possible line of traverse. Our dumps of food were small and we were delayed by weather and conditions so that we had to press on as fast as we could. Tilman, during our last few days in the basin, had developed a carbuncle on his foot and these forced marches must have caused him considerable pain; but he insisted on carrying his share of the loads and never murmured a word of complaint. Crossing the Durashi Col on July 1 we reached Joshimath in pouring rain on July 2. Here we spent a few days resting, eating, and making plans for our next move.

To the north-west of Joshimath lies the Badrinath range, which gives birth to the three sacred rivers, Bhagirathi, Mandakini, and Alaknanda, the three head streams of the Ganges. Though the birthplace of the Holy River of India is the goal of all devout Hindus, surprisingly little is known about the topography of the watershed itself. Our chief concern last year lay in the Nanda Devi basin, but it was decided to devote the monsoon period, when heavy rain and snow would make work so far south impossible, to an attempt to make a complete crossing of the range from Badrinath, first over to Gaumukh at the source of the Bhagirathi, and then over to the Kedarnath valley-system at the source of the Mandakini. In this way we hoped to connect up the sources of these three rivers. We hoped also to be able to trace the watershed as far as time and weather permitted, and to fill in roughly some portions of what might well have been left a blank space on the Survey of India Maps.

Several expeditions had visited various parts of the range. Before the War, Mr. C. F. Meade with the two Alpine guides, Pierre and Justin Blanc, went up the Alaknanda valley and, reaching a gap in the range, were able to look down on to the glaciers flowing to the north-west. In 1931 the Kamet Expedition spent two weeks exploring the head of the Arwa valley and discovered two passes, which if crossed completely would undoubtedly lead eventually to the Gangotri glacier; while in 1933 an expedition led by Mr. Marco Pallis visited and explored the lower reaches of that glacier, perhaps the longest in the Central Himalaya.

We reached Badrinath on July 11, and on our arrival we received a welcome visit from Master Ram Serikh Singh, former Professor of Philosophy at the University of Bhagalpur. The Professor has now retired and spends the

summer months in solitary contemplation in one or other of the beautiful alpine glens near Badrinath. The word professor perhaps conveys the wrong idea of the man, for he was a robust and imposing figure whose whole appearance harmonized with the magnificent mountain scenery amongst which he lived. He was kind enough to spend the whole evening with us, and gave us a fascinating discourse on the history and mythology of those parts, on which subject his knowledge appeared to be boundless. He has travelled extensively and has made, among other journeys, the pilgrimage round the holy peak of Kailas, in Tibet. From him we received a great deal of encouragement in our project.

The next morning we left Badrinath and made our way along the northern bank of the Alaknanda. We had with us enough food for more than three weeks and eight local coolies to assist with the transport as far as the head of the valley. Friday the 13th lived up to its evil reputation for providing ill luck. We were confronted early in the morning by a stream of quite moderate dimensions, as compared with the ones we had encountered in the Rishi Nala. While fording it Passang lost his footing and was swept away load and all by the current. Fortunately for him his load broke loose and sailed down the stream, and he managed to save himself from having his head dashed against the rocks. He lost his ice-axe and in trying to rescue the load Tilman lost his. The load was stopped and brought in before it was swept into the Alaknanda, where it would have been irretrievably lost. Passang was badly shaken and later the loss of the ice-axes proved serious.

Three days' march from Badrinath took us to a point some 5 miles up the Bhagat Kharak Glacier (pronounced Bhagrathi by the natives). There the valley takes a gradual bend of some 37° to the north. Opposite us there rose a massive snow peak which we identified as the G.T.S. peak Kumaling, 23,420 feet high, the highest peak of the Badrinath Range. To its right lay the col visited by Mr. Meade. The route to it appeared to us to be in danger of being swept by ice avalanches. We took the local porters on for another day, carrying heavy loads of juniper firewood collected lower down the glacier, and camped right at the head of the moraine-covered part of the main glacier at an altitude of 16,200 feet. From here we discharged them and were left again to our own resources. On the following day (July 16) Tilman and I climbed a peak which commanded a superb view of the cirque of mountains which encloses the head of the Bhagat Kharak. The cliffs of this cirque are some of the most precipitous I have seen.

After making a rough exploration of the lateral glaciers of the cirque we started northwards. We were carrying enormous loads and our progress was rather slow. The weather too, which had been fair up till this time, became bad. The snow conditions were abominable, and however early in the morning we started we never found a surface crust to prevent us from sinking in up to our knees and even to our waists. In all my mountain experience I have never struck such continuously bad snow conditions. Things had been very different when we were in the Arwa valleys about the same time of year in 1931.

During the next week we crossed a series of passes to the north, each between 17,000 and 20,000 feet high. This landed us in the Arwa glacier system, and we were thus able to connect up the lateral valleys of this part of

the watershed. We climbed (July 22) another peak of 21,000 feet which provided us with excellent mountaineering but no view.

As we got farther north the mountains took on a more rounded appearance, which suggested that we were approaching the border of the Tibetan plateau. We passed several of those curious glaciers which are such a typically Tibetan feature and which appear to have no névé. Having reached the glaciers of the Arwa system we turned west and crossed the main watershed on July 25 by a col of 19,400 feet, probably one of those visited by Captain Birnie in 1931. From now on we left dumps of food and fuel against our return. This lightened our loads and we were able to press forward at a good speed.

When we reached the Gangotri glacier two days later we were surprised to find that we were only about $2\frac{1}{2}$ miles above its snout. We camped here in a little garden of wild flowers, which provided us with a welcome contrast after so long amid the harsh colourlessness of the glacier regions. The following day (July 28) we went down to Gaumukh, chief of the sacred sources of the Ganges. Thus for the first time had a route been made across the range between the headwaters of the Bhagirathi and the Alaknanda rivers.

Half a mile above the snout of the Gangotri glacier another large valley comes in from the north-east. How this fits into the puzzle of the northern part of the range I cannot say. A whole season devoted to the exploration of this fascinating section of the range by a competent party interested primarily in the unravelling of topographical problems should produce interesting results.

We would have given much to have been able to make a push for the untrodden upper reaches of the Gangotri glacier, and if we had had four days' food to spare I think we would have been able to reach its head. But our food was exhausted and we had to make all possible speed back by the way we had come. Our return journey was a lot easier for having no food to carry, as each evening we picked up one of the dumps we had left. From the head pass we made our way down the Arwa valley in bad weather and so reached Badrinath on August 2.

Of the many legends of these parts believed to have been founded on fact is a story that, many hundred years ago, there was no high priest of the Kedarnath Temple, and that the high priest of Badrinath used to hold services in the temples of both places on the same day. The shortest known route between the two temples was well over 100 miles, and over a high mountain pass at that. Tradition has it that a quick way across the watershed was known to the priests of those days. But though the natives believe that the two places are only $2\frac{1}{2}$ miles apart, in actual fact the distance is some 24 miles as the crow flies.

Our observations from the Bhagat Kharak had suggested to us that if a pass could be forced from the head of the Satopanth, it would lead us into the Kedarnath valley system. If this proved to be the case we should stand very little chance of getting down on the other side owing to the immense depths of the valleys there. However a view from the crest of the ridge would solve for us many interesting problems. We had intended to return to the Rishi Ganga about August 10, and August had already come round. But by now we were thoroughly absorbed in the manifold problems of the watershed, and to have to come away without investigating the head of the Satopanth glacier would have left our task only half finished.

A peak on the eastern rim of the Nanda Devi basin

A dense mantle of cloud still hung over the peaks as we left Badrinath and plodded once more up the valley towards Mana on August 5. We had brought with us provisions for only twelve days, and four local men to assist with the load-carrying up the lower part of the Satopanth glacier. Remembering our little contretemps with the Bhasudhara stream a few weeks before, this time we kept to the southern bank of the Alaknanda. When we reached the junction of the glacier we bore to our left and followed a lateral moraine of the Satopanth glacier. We found that this branch was the more frequently visited of the two, and that the grazing extended far up the side of the glacier. Some tiny shrines and quantities of prayer flags suggested that this part of the country was as sacred as Bhasudhara itself. The going was easy, and in three days we were able to pitch camp (August 7) near the head of the Satopanth glacier. From here we discharged the local men.

Early in the morning of August 8, carrying heavy loads, we started towards an obvious gap below the tremendous southerly walls of Kumaling. Throughout the day we worked slowly up the ice-fall which forms the head of the Satopanth glacier. But at length, when only 1000 feet from the col, we were brought up by a huge crevasse which, running from one side of the glacier to the other without a break, formed an impassable barrier. We were forced to camp where we were in heavily falling snow. Throughout the night the gulleys and hanging glaciers of Kumaling kept up a continuous bombardment of ice avalanches from which however we were protected by the crevasses about us.

The following day, in thick mist and falling snow, we managed to find our way off the glacier on to some rocks to our left, and by the middle of the afternoon we reached a level expanse of snow which forms the crest of the col. We hunted about to try and get some idea of our surroundings, but visibility was restricted to a few yards, and at length we decided to remain where we were lest we should blunder into some avalanche-swept area. For the next eighteen hours the heavy mist enveloped us. It was extremely tantalizing, as we were far from sure where the gap was leading us to. I had an idea that we should find ourselves at the head of the Gangotri glacier.

At 7.30 the next morning (August 10) Tilman and I set off to reconnoitre. The snow had stopped falling and our tracks provided sufficient safeguard against the possibility of losing ourselves. We worked down for twenty minutes before we were brought up on the brink of an ice-cliff. We were looking for a way out of this difficulty when all of a sudden the fog rolled away from us and we found ourselves looking down a glacier of tremendous steepness into a narrow ravine-like valley some 6000 feet below. It was now obvious that we were not on the Gangotri ice-stream, and we concluded that we must be looking down into the Kedarnath valley system. The glacier we were on descended in a series of three exceedingly steep ice-falls, separated from each other by small ice plateaux.

We returned to find that the Sherpas had already struck camp and were waiting for our return. We shouldered our loads and hurriedly started the descent. All through the day we worried our way down the intricate tangle of ice, halting only once for a meal. The mist hindered us a good deal, and several times we were forced to retrace our steps for a considerable distance before we could find a way through the maze of crevasses and séracs.

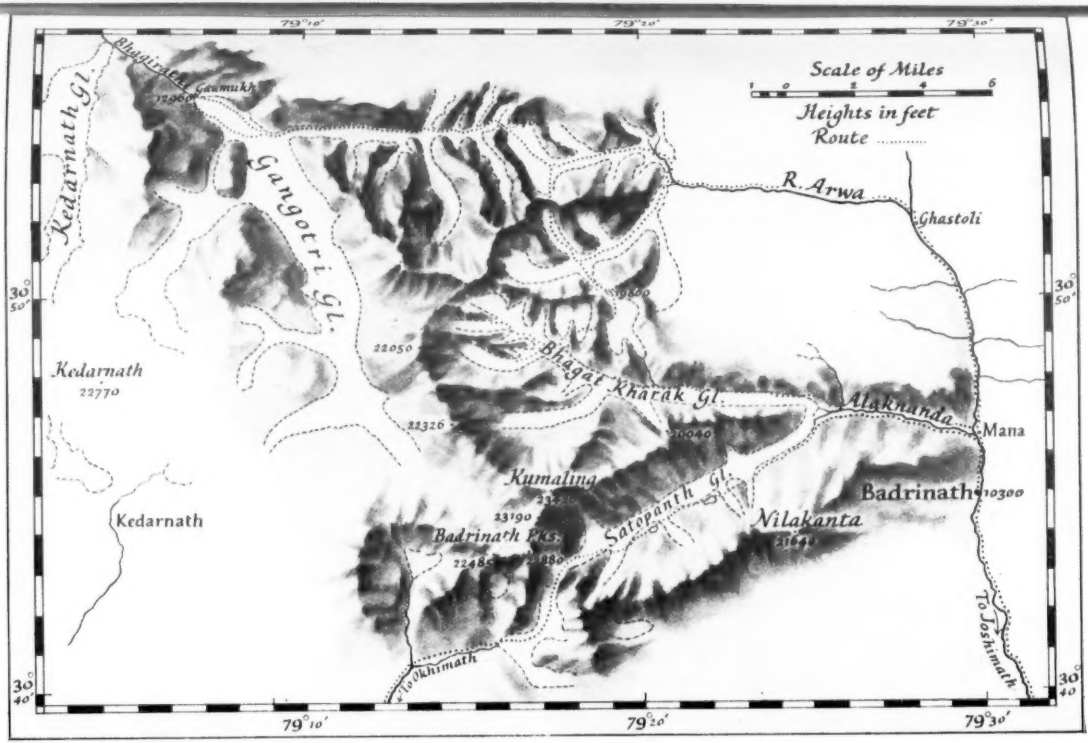
ad of the main ice-stream of the Bhagat Kharak Glacier

Late in the evening we reached the brink of the glacier's final downward plunge. We were now working on dry ice and much step-cutting was required. The angle of the glacier was becoming so steep that we began to think that we were on a hanging glacier. Indeed the prospect of getting down the last bit appeared so hopeless that Tilman and I would have decided to abandon the attempt had it not been for the extraordinary enthusiasm of the Sherpas, who insisted upon investigating every conceivable possibility. Here was another striking example of the loyalty of these men. What we were doing must surely have seemed very pointless to them; and yet, because we had shown our desire to get down to this valley below us, they were willing not merely to follow us, but to undergo any amount of labour, to face any danger in order that we might fulfil our purpose. At dawn the next day (August 11) we resumed our task and eventually succeeded in lowering our loads and ourselves into a steep rock gulley at the side of the ice-fall, by means of our 180 feet of climbing rope. We were able to climb down the gulley and so to reach the level glacier which lay at the foot of the great ice-fall.

At sunrise that morning we had had a fine view of the country to which we were descending. Beyond the glacier we had seen what we took to be a pleasant grassy valley; beyond this dark vegetation stretched away as far as the eye could see. This we took to be pine forest. Two days' marching at the most, we thought, would take us through this agreeable-looking country to some habitation. Also it seemed reasonable to suppose that we should strike some path and be able to cover, if necessary, some 12 miles a day. We knew that it could be no very great distance from the snout of the glacier to the Kedarnath pilgrim route. We were soon disillusioned. Immediately on leaving the glacier we found ourselves in dense undergrowth. We now struck really bad weather. Rain fell in torrents most of the day and night. All our kit got waterlogged, which made the loads very heavy, and the task of hacking a way a tedious one.

On the evening of the first day (the 11th) we reached the brink of a sheer drop of 1000 feet in the floor of the valley. For a short distance above this the river disappears underground and spurts out of the side of the cliff in an impressive waterfall. In camp above this precipice we took stock of our position. Our food supply was beginning to run short and what remained of the *satu* and *ata* was soaking wet and was rapidly going bad. A discussion of the problem as to whether we should go on or turn back lasted late into the night. It was a difficult decision to make, but the prospect of retracing our steps and committing ourselves once more to the icy slopes we had just left did not appeal to us, and eventually we agreed to go on down.

The precipice provided us with more rock climbing than we were then inclined for, but by roping down the worst sections we reached the forest at its foot. Here, under the spread of giant trees, the undergrowth was not so thick, and we made good progress until we reached the upper limit of bamboo at about 10,500 feet. The bamboo shoots were ripe for eating, a fact which undoubtedly saved us from a very serious predicament. We were also able to collect a small supply of forest-mushrooms, which, though they did not last long, gave us one or two square meals. The forest was full of bear-tracks, which greatly alarmed the Sherpas, so that they sang and shouted all day long



The Badrinath Group, from a compass sketch

Glacier table in the southern section of the Nanda Devi basin

Porters from Mana smoking the ceremonial pipe

in order
only got
the black
Late i
formidab
in a perfu
for a wa
however
trouble
falling o
up with
frightfu
Beyo
was exc
ourselve
thorn-s
were ha
at 5.30.
which
bamboo
most ex
have ha
vided
a sorry
We
the goo
Madm
tance
gave u
handfu
willing
We
reache
whose
But
and K
Tim
weath
six ma
On
Devi
to rec
possi
packi
29th
' T
the Su

in order to frighten the animals away. This they did so effectively that we only got one close view of a bear during our sojourn in the forest. He was of the black variety.

Late in the evening of the 12th we reached a narrow gorge containing a formidable torrent coming in from the north. During the whole of the 13th, in a perfect deluge of rain, which made the visibility extremely bad, we searched for a way across this obstacle without success. On the following morning however we managed to bridge the stream near its mouth. Here further trouble befell us. Passang had a small bone in his foot broken by a boulder falling on to it. This put him out of action for any work, and the task of keeping up with us over the precipitous country which followed must have caused him frightful pain.

Beyond the gorge the going became very bad indeed. The side of the valley was exceedingly steep and we had to hang on to the undergrowth to prevent ourselves from sliding down, while we hacked our way through the dense thorn-scrub. At times it took us as much as an hour to cover 25 yards, and we were hard put to it to go more than a mile a day. We used to halt each evening at 5.30. This gave us just time before dark to build a bamboo shelter under which we could protect a fire from the pouring rain, and so cook a meal of bamboo shoot and tea. Dead bamboo, however sodden it might be, makes most excellent kindling, and without it and a fair supply of paraffin we should have had to have foregone the luxury of a fire. Thus this excellent plant provided us with shelter, fire, and food. Without it our plight would have been a sorry one.

We made our way through this type of country for five days after crossing the gorge before we reached (August 18) the tiny hamlet of Gaundar in the Madmaheswar valley. This was nine days after reaching the col, an air distance of 6 miles. The few inhabitants were very poor, and though they gladly gave us shelter we had the greatest difficulty in extracting from them a few handfuls of flour and a cucumber. For these we paid lavishly, but quite willingly.

We now got onto a good path, and on August 20 in the still torrential rain we reached the temple of Okhimath [1] where we were received with a hospitality whose warmth will live amongst my most cherished memories.

But the high priest, who made a practice of holding services at Badrinath and Kedarnath on the same day, was surely a little overworked.

Time was getting short and we could not afford to halt anywhere. In bad weather we crossed a beautiful pass to Chamoli and so reached Joshimath in six marches from Okhimath.

On August 27 we began our hurried preparations for our second Nanda Devi expedition. Early that morning Angtharkay started off with instructions to recruit fifteen men from the Mana valley and return with them as soon as possible. Meanwhile we were busy working out ration lists, collecting food, packing up, and planning our last little campaign. Late on the night of the 29th Angtharkay arrived with as tough a squad of men as we could have

[1] This is the spelling employed by the temple authorities. It is spelled Ukimath on the Survey of India map and pronounced locally more like Weekimāt.

Glacier table in the southern section of the Nanda Devi basin

Porters from Mana smoking the ceremonial pipe

wished. He brought also kind messages of congratulation from His Holiness the Rawal and other of our friends in Badrinath. We were particularly gratified to get a message from Master Ram Serikh Singh who, on hearing of Angtharkay's arrival, had rushed down from his camp in the lovely valley below Nilkanta to hear our news. From him we learnt that while we had been on the Satopanth pass, Badrinath had experienced some of the worst weather on record, and that there had been a belief that we were lost.

We left Joshinath on August 30 and camped that night at Tapoban. The weather was still bad and we were somewhat worried about our food getting wet. We reached Durashi this time in four marches *via* the Lata Kharak. When we got into the Rishi Nala we found that a great many landslips had occurred in our absence. The rains must have been terrific. Some small, steep side *nalas*, normally dry and with very little collecting capacity, showed signs of having had as much as 7 feet of water coming down them. We were now able to appreciate the tremendous advantage of local knowledge when traversing difficult country. Across places which had previously cost us hours of anxious toil we were now able to lead our party safely in half the time. We used the high-level route and crossed the Rhamani 1500 feet above its junction with the Rishi.

I should like here to pay a tribute to the skill and willingness of the Mana men. They had not, of course, to undergo the hardships which the Dotials had suffered on our first journey, but before very long I came to have considerable respect for them as cragsmen, while their ever-ready wit and carefree laughter will remain as one of my pleasantest memories. They and the Sherpas came to be the very best of friends and I think there was a measure of genuine regret when the Mana men had to take their departure.

We reached our old base-camp in the Rishi Nala on September 5. From here on we knew every inch of the route and were able to take ten of the Mana men with us. It was by a lucky chance that none of the vital points of the traverse had been seriously altered by the landslips. On September 8 we reached the basin and discharged the Mana men. We established a base near the snout of the southern glacier (about 14,000 feet) which we were surprised to find is over 3 miles above the junction of the two streams. The weather now (September 9) became fine and we were able to work without interruption. We found the southern section to be a great deal less complicated than the northern.

There are two main ice-streams which cover the floors of the upper valleys. The larger of the two rises in the great snow-fields which form the northern face of the highest peak on the southern rim of the inner basin, which is called by the Survey of India East Trisul, but for which I would suggest the name Maiktoli Peak, from the local name Maiktoli of the grazing ground to the south-east; or perhaps better, Maiktoli for both peak and grazing ground, if there is no objection to the same name, as in Dunagiri. It flows in a northerly direction and ends abruptly 100 yards from the snout of its rival. The smaller glacier rises partly under the grim precipices which form the south-east rim of the basin and partly from vast ice-fall which extends a long way up the southern face of the Nanda Devi East. The tributaries of these glaciers are few and of no great consequence.

We were extremely anxious to force a route either across the ridge which connects Nanda Devi East with the southern rim (which Dr. Longstaff had reached in 1905 from the Milam side), or towards the south across the col by which Mr. Ruttledge and the guide Emile Rey had attempted to get into the basin in 1932. I am afraid that our activities in the southern section were governed largely by this ambition.

On September 11 we set out to climb Maiktoli. We put a camp at about 20,000 feet on the glacier face referred to above. Tilman became unwell on the way up and unselfishly went down with Passang in order that Kusang and Angtharkay should be able to occupy the camp with me in his place. The next day we climbed the peak (22,320 feet) in bad conditions. We encountered a severe wind which was almost up to Everest standard. All the way up and from the summit we saw views of surpassing grandeur. Even the great southern faces of Nanda Devi seemed to be dwarfed by the mere extent of the panorama. West and north, Badrinath, Nilkanta, Kamet, Ghori Parbat, Dunagiri, and their numberless satellites merely served as a foil the better to display those extraordinary ranges towards the borders of Nepal. To the south, at our feet, lay the little Simm Saga range, beyond this was a cloud sea stretching as far as the eye could reach.

On September 15 from a camp far up on the left bank of the eastern glacier we climbed to about 20,500 feet on a south-eastern ridge of Nanda Devi in order to get a comprehensive view of the southern section of the basin. On September 17, having completed to our own satisfaction the reconnaissance of the southern section we set out to attempt the crossing of the col on the southern rim. We were carrying food sufficient for twelve days, which we had found was the maximum we could manage without having to make double journeys. The climbing on the northern side was easy but on the southern side we became involved in very difficult work which kept us hard at it for two long days before, late in the evening of September 20, we reached the little grazing ground of Maiktoli. Although this gap provided us with a means of escape from the basin it would probably be too severe a task to tackle it in the reverse direction, particularly if heavy loads were carried; and I fully endorse Mr. Ruttledge's judgment in abandoning his attempt of 1932.

These last two days provided a fitting climax to our little season of supreme happiness. There followed the marches back over the wooded foot-hills, whose ravishing beauty must leave an indelible memory with all those who have travelled amongst them. Behind us, floating in the upper air, were the giants whose presence we had just left. So ended at Ranikhet five crowded months, amongst some of the most glorious mountains of the world.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: We are going to hear to-night an account of an exploration of the Nanda Devi basin and the Ganges watershed. Those of you who have been in India will probably remember Ranikhet and Almora in the district of Kumaun, a very beautiful bit of country for a starting-point. We are going to hear of the task, a very difficult one, of penetrating into the basin surrounding the great mountain of Nanda Devi, the highest peak in British India, 25,600 feet, and a very beautiful peak,

too. Mr. Shipton and his companion, Mr. Tilman, own properties in Kenya. Mr. Shipton, it will be remembered, came to England when he heard of the plans for the last assault on Mount Everest in the hope of being able to join that expedition. When that was over he thought he would make another journey in the Himalaya before returning to East Africa, and Mr. Tilman, with whom he had climbed a good deal in East Africa, came and joined him in his Nanda Devi project. They were a very small party, themselves and six porters, but they accomplished a very fine piece of work which Mr. Shipton is now going to describe. Without more ado, I ask him to read his paper.

Mr. Shipton then read the paper printed above, and a discussion followed.

The PRESIDENT: Mr. Tilman has promised to add a few words. I now call on him.

Mr. H. W. TILMAN: I have never previously faced an audience, and I beg to be excused more than a word or two. Really, there is nothing for me to add to what the lecturer has said. He has made clear every aspect except, of course, what he himself did. I should like to say that these small successes of ours were not quite fortuitous but mainly the result of very careful planning on the part of the leader. He expressed appreciation of the work of the Sherpas, but it must be remembered that those men will only give of their best under such leadership as we enjoyed. He also observed that we climbed on the shoulders of our predecessors, so I venture to hope that means will be found to build upon our work, in the near future.

The PRESIDENT: As you know from what the lecturer said early in his paper, he owed to Dr. Longstaff the idea of undertaking this particular piece of work. I hope Dr. Longstaff will come and address us.

Dr. T. G. LONGSTAFF: I am familiar with the mountains of Garhwal; I think they are the most beautiful part of the Himalaya. I also know a good deal about all the expeditions which have been there, and I do not know of any which has done more or better work than that of which we have heard to-night. The success achieved by Shipton and Tilman is a shining example of concentration on the tactical objective through every stage of the expedition. They have solved the problem of the Rishi gorge—so difficult that they took nine days to cover the last untrodden 4 miles. I did not get through; therefore I am very glad they took nine days over it because no one can say it was very easy. They thus had the tremendous excitement of being the first human beings—because no natives have ever been there—to enter the inner sanctuary of Nanda Devi. Incidentally, the double peak of Ushba, the most celebrated peak in the Caucasus, is very like Nanda Devi except that the latter mountain happens to be twice as high. Their base camp at the immediate foot of Nanda Devi was at 13,000 feet, and the top of Nanda Devi was 12,600 feet above that. Is there any steeper scarp in all the Himalaya?

After all this excitement they solemnly concentrated on exploring the northern basin, and throughout the whole of the trip they were plane-tabling: they have brought back a survey of the ground they have covered, which is a vast improvement on the old maps. When caught by the monsoon they went off and completely connected up the Badrinath–Gangotri and the Badrinath–Kedarnath glacier systems, perhaps the most arduous work of all in view of that appallingly steep ice-fall. This time they managed to do 6 miles in nine days, 2 more miles than they had done in getting up the gorge of the Rishi. That extra 2 miles entailed living on bamboo shoots and fungi, which the lecturer politely called mushrooms. After the monsoon they returned to the south basin of Nanda Devi and actually climbed up Nanda Devi itself to 20,500 feet. We saw a fine

picture of their descent of the great ice-falls above Maiktoli, a feat demanding the highest sort of mountaineering competence.

There are many remarks I could add with regard to this piece of work, the finest that has ever been done in the district. It is surely a striking proof of what all experienced travellers know: that individual competence and the personal qualifications of the traveller are far more important to his success than the size of his bank balance. These two men, both, I am glad to say, fellow-members of the Alpine Club, and of course skilled mountaineers who have climbed many difficult heights, did their work accompanied by only three Sherpas. They carried loads themselves: they did their own work and yet, at the same time, they continually used the plane-table and, as I have said, brought back a survey of the ground they traversed. They spent five months in the Himalaya, using cargo boats out and home—seven months in all—at a total cost of £287: £143 10s. apiece. It is certain that lack of funds always entails extra hardships, but if their resources had been multiplied tenfold, could these two men have done more than they have done? Personally I do not think anybody could have done more. In this respect, as in many others, they have set up a standard hard to follow.

Brigadier E. F. NORTON: You have called upon me quite unexpectedly, Mr. President, and I have to hurry to catch a train. Nevertheless, I am glad to have this opportunity of expressing my admiration for the expedition about which we have heard. I regard it as the ideal type of expedition—a type of which we have seen all too few in the Himalaya since Dr. Longstaff first set the fashion. Since the Mount Everest Expedition everybody has, of course, been aware of Mr. Shipton's reputation, but not so many know Mr. Tilman. I had the privilege of working with him nearly twenty years ago during the Great War. From what I knew of him then I am not at all surprised to hear that he was so able a seconder of so fine a leader. I must now catch my train, but I should like once more to congratulate the lecturer not only on his lecture and his beautiful pictures but on the modesty with which he told his story.

The PRESIDENT: We have with us the President of the Alpine Club, and I hope he will give us some comment from the point of view of the alpinist.

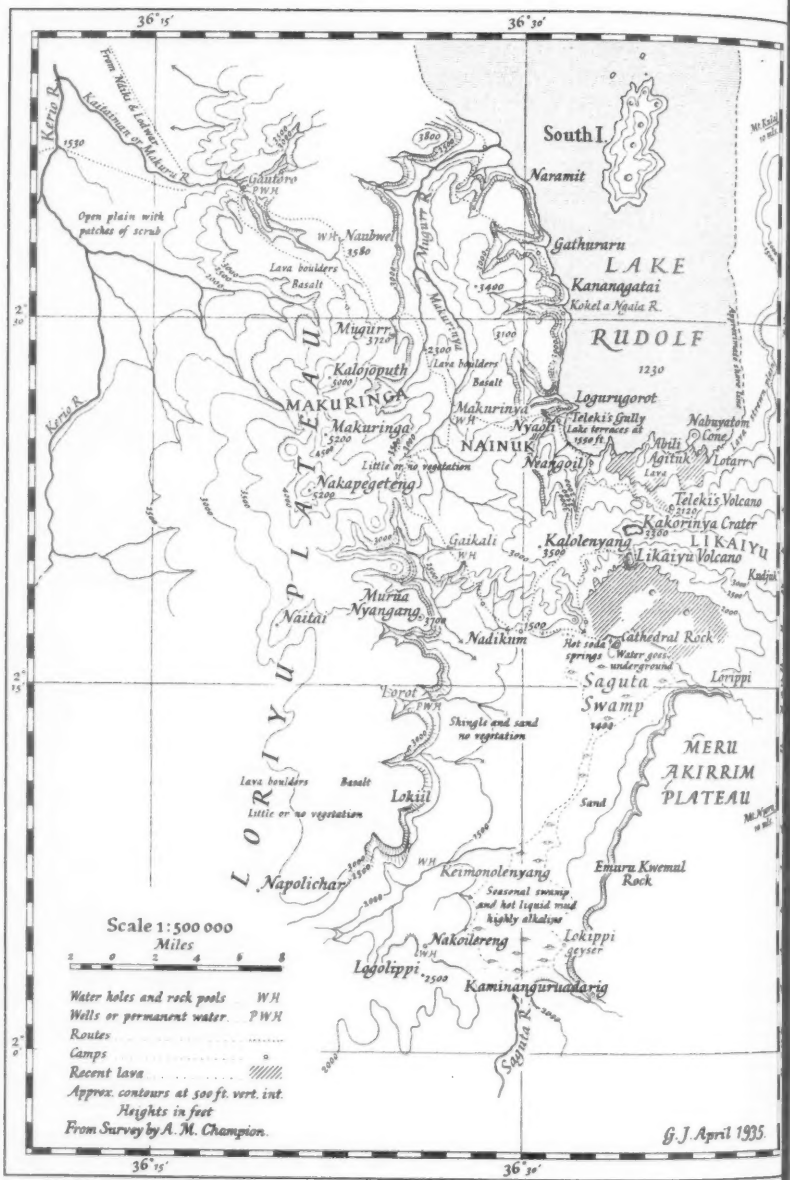
Colonel E. L. STRUTT: I feel, like Brigadier Norton, that I ought to run off to catch a train, but as I have been called upon, as President of the Alpine Club, to comment on this most remarkable expedition I can say, honestly, that I have not been within 1200 miles of the district. Therefore I am hardly an authority on it. I do however know something of the ground that Dr. Longstaff and Mr. Graham traversed, and I can endorse Dr. Longstaff's remark that we have heard described one of the finest bits of exploration that has ever been carried out.

As has been said, we all know Mr. Shipton's record. Mr. Hugh Ruttledge told of his exploits on Mount Everest. Some of us are not quite so much up to date with Mr. Tilman's record. All I know of Mr. Tilman, beyond the personal acquaintance of which I am very proud, is that he last year crossed Africa from east to west on a push bicycle. During that period he spent, I think I am right in saying, six days in making a solitary ascent, that is without a companion of any kind, of Kibo, the highest peak on Kilimanjaro. That proves him a pretty tough specimen.

The PRESIDENT: You have heard such eloquent tribute paid to the travellers' performance that there is little more that I need say. They have undoubtedly carried out a most wonderful piece of work, and the ridiculously small sum for which they managed to do all they did was indeed a triumph of economy. We heard from them what they did during daylight and how they camped for the night and at 7.30 a.m. they proceeded onwards and so on, but they told us nothing of their night experiences on the mountain. In fact it was difficult to realize

while Mr. Shipton was lecturing in the simple way in which he told his story the extraordinary endurance their exploration entailed. They have both referred in grateful terms to the behaviour of the Sherpas, and we know how much we owe to them in connection with climbs in the Himalaya and Karakoram, especially the assaults on Mount Everest; thoroughly reliable and brave men that they are.

Mr. Shipton is, I am glad to understand, planning another expedition. It seems that he and his comrade cannot tear themselves away from the mountains. Let us hope that Mr. Shipton will be able to carry out another expedition this summer, if funds permit, and that we shall hear from him again next winter. I ask you to join me in congratulating him once more on his splendid achievement, and thanking him for the interesting evening he has given us. Mr. Shipton, I am sure you will realize from this very hearty applause how much we have appreciated your lecture.


36° 15′
36° 30′
2° 30′
2° 15′
2° 0′
South I.
Naramit
Gathuraru
LAKE
Kananagatai
Kokel a Ngaia R.
RUDOLF
1230
Kerio R.
Kaisatimon or Makuru R.
From Nikile & Lorwai
Gaiuforo
PWH
Open plain with patches of scrub
WH Naubwei 3580
Lava boulders
Basalt
Mugurr 3720
Mugurr R.
Makuringa R.
2300
2100
3400
Lava boulders
Basalt
Kalojoputh 5000
MAKURINGA
PLATEAU
Makuringa 5200
Makurinya WH
Nyaoli
Logurugorot
Teleki's Gully
Lake terraces at 1550 ft.
NAINUK
Nabuyatom Cone
Mbili
Agitiuk
Lotarr
Neangoil
Lava
Little or no vegetation
Nakapegetong 5200
Teleki's Volcano 2120
Kakorinya Crater 2300
Kalolenyang 3500
LIKAIYU
Likaiyu Volcano
Kadjuk
Gaikali WH
Murua Nyangang 3700
Naitai
Nadikum 1500
Cathedral Rock
Hot soda springs
Water goes underground
Saguta Swamp 1400
Lorippi
Lorot PWH
Shingle and sand no vegetation
MERU
AKIRRIM
PLATEAU
Mt. Ngiro
Lava boulders
Basalt
Little or no vegetation
Lokiil
Sand
LORIYU
Napolichar 3500
WH
Keimonolenyang
Emuru Kwemal Rock
Seasonal swamp and hot liquid mud highly alkaline
Lokippi geyser
Nakoilereng WH
Logolippi 2500
Kaminanguruadarig
Segula R.
Scale 1:500 000
Miles
2 0 2 4 6 8
Water holes and rock pools WH
Wells or permanent water PWH
Routes
Camps
Recent lava
Approx. contours at 500 ft. vert. int.
Heights in feet
From Survey by A. M. Champion.
G. J. April 1935.

TELEKI'S VOLCANO AND THE LAVA FIELDS AT THE SOUTHERN END OF LAKE RUDOLF: *A paper read at the Evening Meeting of the Society on 7 January 1935, by*

A. M. CHAMPION

IT was towards the end of 1928, while I was making preparations for a *safari* to demarcate the boundaries of certain Native Reserves, lying to the south and south-west of Lake Rudolf, that I became aware that one of the pivotal points on which my work rested was Teleki's volcano. I had hardly heard of it before, and to my surprise the Director of Surveys, Mr. A. G. Baker, admitted that though mentioned in the official descriptions of the Provincial Boundaries he was not only uncertain of its position but of its very existence, and suggested that I might be of some assistance to his Department.

As so often happens in Government Service, after three months in the field orders were received to close down work and proceed elsewhere. At the time I was still about 90 miles from the reputed position of the volcano, and it was not till 1932 that an opportunity again came my way to explore this area. I was then in charge of the Turkana Province, and it was obviously one of my duties to inspect the Provincial boundaries and at the same time to put an end to this mystery about Teleki's volcano. That there were grounds for doubt in Mr. Baker's mind is borne out by a passage which appeared in this Society's *Journal* of April 1898 in an article contributed by Mr. H. S. H. Cavendish. It reads as follows:

"On arriving at the south end of the Lake (Rudolf) I was surprised to find Teleki's volcano had entirely disappeared, its place being taken by an entirely flat plain of lava. We got hold of some of the Ligob-men who live at the south end of Lake Rudolf and within a couple of miles of the volcano, who told us that about six months ago the lake overflowed and as the waters rushed towards the mountain, the native name of which is Lobburua, there was a vast explosion, after which the waters swept in where the crater had been and put out the fire."

The *Encyclopaedia Britannica*, based perhaps on the above source of information, reads: "Great changes are reported since 1889. In particular the Great Volcano of Lubburua (Teleki's volcano) at the south end of the lake is said to have been destroyed between 1889 and 1897 by a sudden explosion."

If we study the map of the area it will first be noticed that it depicts a long north and south depression with hills on either side. Across this depression runs a range of hills forming a barrier across the valley on the north of which lies Lake Rudolf and on the south the Saguta swamp. The hills therefore stand up in the shape of a letter H, which fact, as I shall hope to demonstrate later, is one of the most interesting features in the topography of the area. This long depression is of course the main Rift Valley extending northwards into Abyssinia and the Red Sea, and southwards to Baringo and Naivasha. The floor here stands about 1200 to 1300 feet above sea-level, and is therefore the lowest part of the Rift Valley in Kenya. Lake Rudolf was computed at 1250 feet above sea-level in 1901 by Major H. H. Austin, but the water-level appears to have fallen since then, as is evidenced by the complete drying up of Sanderson Gulf in the north-west corner, so that according to my calculations it stands

now at 1230 feet. Thirty-three years ago the Gulf was a sheet of water 30 miles in length, 8 to 10 in breadth, and connected with the lake by a sound 3 miles wide. During the last four years the level has sunk at the rate of about a foot a year. This would appear to be due to a marked decrease of rainfall in recent years over a large portion of the catchment area from which the lake derives its supplies.

The main drainage area lies to the north and west, the only permanent feeder being the Omo river, which has its source in the highlands of Abyssinia. The Turkwel river, which rises in Mount Elgon, where it is for its first 100 miles known as the Suam, empties surface water into the lake for three or four months only in the year. The Kerio, which rises near Eldama Ravine, contributes surface water for an even shorter period. Though in the distant past there is every reason to suppose that there was an outlet to the north connecting the lake with the Nile basin, at present there is none, and as is only to be expected, its waters are so brackish as to be hardly potable. The slimy feeling when in contact with the skin is probably due to the presence of sodium carbonate. They contain, in addition to large numbers of crocodiles, great quantities of Nile Perch (*Lates*). These are now being caught on night lines for feeding the Turkana, and though some big ones have been taken, Dr. Worthington's 214-pounder is still the record. The peculiar situation of the lake subjects it to the most violent winds which spring up in a few minutes and whip the surface into the most dangerous cross seas in a very short period of time (Plate 1).

The lake was discovered by Count Samuel Teleki in 1888, who, accompanied by Captain von Höhnel, started out from Zanzibar in 1886 with five hundred porters and returned three years later with but two hundred. His amazing adventures were recorded by his companion, who is still alive and takes a great interest in the development and geographical problems of this part of Africa. The larger lake was named after the then Crown Prince of Austria, whilst a smaller one which Count Teleki also discovered farther to the east was called Stefanie, after the Princess. To the active volcano the name of the leader of the expedition was given.

The volcano when discovered was in such activity that Teleki had perforce to make his way round the southern side, as he was unable to cross the stream of molten lava which enveloped its northern and eastern sides, and extended for a distance of 5 miles to the shores of the lake. Whilst his caravan was making this arduous detour he made a valiant attempt to reach the summit, but was driven back by the fumes emanating from long fissures which rent the mountain side and rendered further progress impossible. He makes mention of some natives inhabiting the vicinity called the Lokob, who would appear to be fisher folk from several of the surrounding tribes now spoken of as the El Molo, who having lost through disease or raids such stock as they possessed were compelled to eke out a living by catching the fish which abound in the lake. He mentions also the Burkeneji, who are undoubtedly a section of the Samburu who now inhabit the plateau to the east of the Saguta valley.

The next traveller to visit these regions seems to have been Mr. Cavendish, who in 1897, though he failed to find the Teleki volcano, discovered another which he describes as in a smouldering condition on the southern slopes of the

1. Lake Rudolf, looking south-east from the mouth of the Kerio

2. Crossing the Loriyu Plateau

3. Gautoro : basalt resting directly on Archaean gneisses and schists

4. Likaiyu or Andrew's cone and explosion vent

5. Saguta river and swamp seen through breach in lip of Likaiyu crater

6. Interior of Likaiyu crater

barrier, and about 4 or 5 miles distant from Teleki's. This he proposed to name the Andrew volcano, after his companion, but the name never seems to have been adopted on maps.

Two years later Captain Welby, coming from Abyssinia, followed Count Teleki's route and found the volcano apparently quiescent. A stream of lava from this same centre of activity he considered, from the condition of trees which had been overwhelmed, to have been in a fluid and molten condition about three or four years previously. More recently Lord Delamere in 1900 and Captain Stigand in 1912 traversed this area, but neither, as far as I am aware, make any mention of the volcano. Possibly their route lay some way to the east, and from it, owing to the conformation of the country, the volcano would not have been within sight. Mr. F. S. Deck, a fellow Provincial Commissioner of mine, assures me however that whilst travelling in the Samburu country in 1917 he distinctly saw black smoke arising from that neighbourhood, but at such a distance that he was unable to be sure if it came from the north or south side of the barrier. Mr. Juxon Barton, a District Officer who during 1921 and 1922 was administering the area to the south-west of the lake, informs me that the Turkana brought him terrifying stories of a mountain of fire, and that he saw at nights a glare in the sky which gave support to their fears and convinced him that there was some truth in their statements. So much for the rather scanty history of this region.

Choosing the month of April as the most promising with regard to water supplies *en route*, I set out from Lodwar, the headquarters of the Northern Turkana District, and met my two companions, Mr. Baker-Beall, the District Commissioner of Southern Turkana, and Dr. Robertson, the Medical Officer at Ndiki, on the Kerio river three days later. We assembled a *safari* of thirty camels of which eight were provided with *baramils*, *i.e.* metal containers capable of holding 10 gallons of water; the remaining camels were but half laden with flour, our personal effects, and camp equipment; we could therefore carry 160 gallons of water, which would afford a three or four days' supply in case of need (Plate 2).

The maps were so lacking in detail that they were of little or no use; we had therefore to rely almost entirely on native guides, who seemed very vague as to what we wanted to see or where we wanted to go, and the fact that we did not quite know ourselves did not make explanation easier. On leaving the river however they set out confidently in a south-easterly direction for a conspicuous re-entrant in the long horizon of the Loriyu plateau, and as we entered this an hour or so after dawn, we struck down on to the Archaean floor of gneiss and schist which east of the Turkwel is covered by a thick sheet of lava. At Gautoro we were fortunate enough to find water in some holes in the sandy river-bed, and filling up all vessels available we traversed up the south side of the gorge, where the junction with the over-lying cap of olivine basalts was very well exposed. At the base the lavas are to some extent decomposed, vesicular, and containing olivine crystals of some size. As the edge of the plateau is approached they become more compact and exhibit in places columnar structure (Plate 3). Here we were met with a strong and continuous blast of hot wind sweeping across a desolate waste of rusty brown lava boulders. Many of the latter had the appearance of being varnished. This is apparently

due to the continual polishing they receive from the fine particles of quartz sand in wind, and is a well-known phenomenon in desert areas. There is little or no vegetation as the wind has blown the soil down into the Kerio valley as if washed away by a torrent. Great care is needed in traversing this sea of boulders. After two hours of it our own fatigue and the sufferings of our transport animals suggested a halt for the night. Along the route we had noticed a number of small stone circles: these we found to have been made by Turkana to shelter themselves and their flocks at night from the fury of the wind. Other travellers have mentioned them as suggesting structures of archaeological interest.

An hour or so after dawn on the following day we stood on the opposite edge of this plateau, looking down some 500 feet on to the sandy valley of the Mugurr river. At the foot we were again on the Archaean floor, and along the cliff there was an excellent example of the successive and parallel fault lines of the Rift Valley. Consultation with a Turkana who appeared to be the sole inhabitant of this valley led us to discontinue our easterly direction and turn almost due south, and before long the presence of a pool of putrid water in a rocky river-bed induced us to pass the night in that vicinity and decide on a really early start next morning by the light of the moon. We were now again on the lavas and tuffs, and the broken nature of the country and the lack of a track caused us later to doubt the wisdom of this decision.

There was nothing for it but to stumble on, and by midday a place called Gaikali was reached, where again we were lucky in finding a little water, and from here our first view of the Saguta swamp was obtained. As we descended during the late afternoon, the wide expanse of sand which occupies the floor of the valley began to open out, and with great triumph our guides showed us a little wisp of steam curling up from the foot of the dark escarpment of the Samburu plateau on the opposite side of the valley and over 20 miles away. Examination through the glasses convinced me that this was but an unusually large steam-jet and certainly could not be the volcano of which we were in search. It was on another occasion visited by Baker-Beall, who found it to be a geyser (called Lokippi) surrounded by a well-formed basin of sinter from which boiling water surged up at regular intervals to a height of about 4 feet. The volume of water was so considerable that he reckoned it gave a new lease of life to the Saguta river, which at that point had practically ceased to flow.

Whilst thus engaged in speculation my attention was arrested by the country to our left, which gradually began to open out as we worked round the shoulder of a hill that had up till then masked our view in this direction. One of the party said: "That looks like the moon through a telescope," and he described it well. We were gazing at the southern slopes of the barrier or horizontal line in the letter H, and cinder cones and craters in all stages of disintegration were thrown into strong relief by the sloping rays of the sun setting behind us. One detached mass standing out like an island in the golden sands of the valley at first suggested to me that this was Teleki's volcano. Closer examination however showed it to consist of horizontal layers of stratified tuff, isolated by erosion in such a manner as to present the appearance of a huge gothic pile. We therefore dubbed it the Cathedral Rock and entered it so on our map. It was then that we became aware of the existence of this barrier

nearly 2000 feet above the lake and separating it from the Saguta swamp. The natives informed us that the river failed to make its way into the lake, but disappeared into a hole at the northern end of the swamp.

At dawn we headed for a little clump of dom palms which seemed to be the sole representatives of the vegetable kingdom in these parts, and there on the edge of the swamp, by digging in a dry watercourse, found a little fresh water. Nadikum was its name, and under the welcome shade of the palms we sat down to think out our plans, eventually deciding to increase our range of search by splitting up into two parties. Baker-Beall elected to strike northwards over the barrier to the lake shore, whilst the Doctor and myself preferred to make an examination of the southern slopes. Between us and the Cathedral Rock lay 2 or 3 miles of yellow mud and water, the home of numerous flamingo. A high water-level was marked by a line of wrack composed mostly of these birds' quills and the skeletons of a fish which Mr. R. E. Dent, the Kenya Fish Warden, has kindly identified for me as *Tilapia nilotica*. The swamp was entirely devoid of vegetation, and an attempt to cross it nearly ended disastrously. A thick heavy black mud underlay the yellow slime, and this contained so high a soda content as to corrode holes in the tin in which a sample was placed. Along the northern edge there were many hot soda springs of crystal clear but quite undrinkable water. Farther along to the east, and nearly opposite the Cathedral Rock, the water showed a slight current towards a spot where it disappeared into the ground and may or may not pursue an underground course to the lake. No evidence has been found of it coming to the surface again. This spot was overshadowed by a huge cascade of black lava which had evidently quite recently poured like porridge over a cliff about 250 feet high. This was found to be composed of a limburgitic olivine basalt and rested directly on the older rocks of which the barrier was formed. They appeared to be trachytes and the associated tuffs.

With some difficulty a suitable spot for a camp was found amongst this mass of cinder and stone. An evening walk brought into view a yellow and black well-shaped cone of very recent origin (Plate 4), about three-quarters of the way up the slopes of the barrier. As far as could be seen from our position the cascade of black lava which we had encountered that afternoon was the termination of a lava flow which emanated from it and passed quite close to the camp. Time would not allow of reaching the cone that evening, and the next morning it proved even farther off than we anticipated. Several big detours had to be made to avoid deep and precipitous gullies, some of which contained flows of this same black lava. When within about a mile of our objective the hard bare ground was lightly sprinkled with lapilli, which as we approached became much thicker, and grey volcanic bombs from the size of a hen's egg to that of a football lay around in great profusion. The lapilli on examination proved to be sharp and angular, and not blown by the wind into sheltered places. Evidently magma had been thrown into the air with considerable violence and come to earth in a semi-molten condition at no very distant date: one is tempted to surmise not more than ten or fifteen years ago.

When within about a quarter of a mile of the cone we were confronted by a lava flow some 300 yards wide. This was rough and jagged with numerous steam-holes and spiracles, quite unweathered and without the least trace of

vegetation. It was necessary to proceed with great caution as the crust of the steam-holes was not only very thin but the broken fragments were capable of inflicting the most unpleasant wounds. On gaining the opposite side, a climb of 150 feet brought us to the lip of the crater, which was found to be compound, elliptical in shape, and with the longer axis oriented roughly north and south. It contained two if not three distinct vents. The southernmost (Plate 5) was choked with lava which had poured out through a breach in the lip shown in the photograph, and from this point the great lava flow which we had seen the previous day, and which covers an area estimated at 12 to 15 square miles, had its origin. The flow can be seen in the photograph extending for some 4 or 5 miles down the southern slopes of the barrier to the Saguta swamp. The river and the Loriyu plateau can be seen in the distance. Detrital material had fallen back in sufficient quantities to choke the throats of the other two vents. The crater was about 80 feet in depth (Plate 6). The inner walls, which near the top were vertical, were hung with chocolate-coloured clinker. There was no thermal activity beyond a slight sense of heat and here and there a few sulphur fumaroles from which fumes may still be issuing. Wisps of steam indicated the presence of numerous steam vents about the country-side. A few hundred yards to the north lay another crater which had evidently been shattered by an explosion and as a result had lost its form, large masses of lava, clinker, and cinder lying about in complete disorder. A mile farther north, and very nearly on the crest of the barrier, we came to the southern edge of a large crater perhaps a mile in diameter. It was evidently older than the others by many thousands of years, and the floor, which was 200 to 300 feet below the lip, was thinly covered with scrub. The southern side had been breached. We returned to camp that evening feeling confident we had rediscovered Teleki's volcano. From subsequent reading I am now convinced however that it was Andrew's cone we had happened upon. The Turkana had no name for it, but the region was called Likaiyu, and so it has now been entered on the map. From the Turkana we could find no confirmation of the place-names which have been used by past explorers, and it is thought that they were of Samburu origin: a derivation supported by the fact that in those days the Turkana had not settled so far east. The barrier appears as Sil in some sketch-maps I have examined.

The following morning Baker-Beall came back, having reached the southern shores of the lake, where he met some Turkana fishermen of the Ngebelai Section. They gave him some fish and some interesting information about the few Europeans who, they said, had travelled these regions long ago when they were small children. He gave us a vivid description of the lava flows and of a big symmetrical cone which jutted out into the waters of the lake. He did not think however that it was of very recent origin and so could not be the one found in eruption by Count Teleki. On the other hand he saw nothing to suggest a recently active volcano. His photographs, when developed later, showed beyond all doubt the relative antiquity and striking appearance of the cone he had seen.

The return journey, except for a wearisome night watering our camels by means of a handbowl from the little trickle of water at Nadikum, was without incident. I began to wonder if the *Encyclopaedia* were right and Teleki's

volcano had really been destroyed by an explosion or could it be the cone which the Doctor and I had examined.

It was not until a month or so had passed and I had managed to procure a copy of Captain von Höhnel's work, that I became quite positive that Teleki's volcano was on the north side of the barrier and not far from the shores of the lake. At the time I was not familiar with Cavendish's records and considered we had found a new volcano which showed very distinct evidences of activity, certainly more recent than 1888. Our knowledge seemed to suggest that Teleki's volcano had been destroyed as alleged, and for that very good reason had not been seen by Baker-Beall.

It would have been disappointing for us to leave the matter as it stood, so a few months later the District Commissioner and his assistant Kennaway set off again, and this time they followed down the Saguta river, passed the Lokippi geyser, and surmounting the barrier started a systematic search on the northern slopes; and Kennaway, as far as I know, was the first white man to reach the summit of what is without any shadow of doubt Teleki's volcano. Unfortunately an injured foot prevented Baker-Beall from accompanying him. With the roughest of instruments, consisting of a compass which was generally very misleading, a camp table, the back of an old blue print, and a couple of pins, Mr. Kennaway produced a surprisingly good sketch-map of the Saguta valley, the barrier, and the rather intricate country lying along the south-west shores of the lake. Subsequently I was able to check the accuracy of his work, and there was but little fault to find.

It was not till August of 1933 that I was able to find the time to undertake another journey to these parts. By this time however I had carried out a triangulation built up on the most northerly points of the Kenya survey, and equipped with my theodolite and large plane-table for the graphic triangulation I set out again from Lodwar. I took a more southerly route on this occasion with the object of establishing two trigonometrical stations before turning eastwards to the Kerio river. These and other intersected points lying between the Kerio and Turkwel rivers were of great assistance to me in the construction of the sketch attached to this paper. Even when the field data are computed, certain adjustments will probably be found necessary as there are some considerable discrepancies with the surveyed points on the eastern borders of Uganda and the southern borders of the Sudan. As this operation will take some time and involve considerable correspondence, it has been thought better to tie this sketch on to major points fixed by the methods described above and regard it as provisional.

This time I proceeded alone, and on reaching Gautoro in the re-entrant of the Loriya plateau I left the camels behind, taking only a pack-mule and four donkeys. By a shorter route I cut across the plateau to the opposite edge, where the position of a small but distinctive knoll was satisfactorily determined. I again dropped down into the Mugurr valley, but instead of turning southwards as we had done before, I refused all advice and kept a steady course to the east across the boulder-strewn country. Providence evidently guided my footsteps, for by half-past five in the evening of the second day I was standing on the eastern edge of the plateau and without doubt at the very point at which Teleki had forced his way up from the lake shore below by a path so rocky and

precipitous that the donkey on which was perched his pet monkey Hamus had lost his footing and fallen over the side. There was no time to be lost: the mule and donkeys were relieved of their burdens and orders issued for the man-handling of the loads. This afforded the time for a few hasty observations and a quick sketch of the panorama which lay before me. The cliff on which I stood flung a deep shadow halfway across the lake, whose semi-transparent waters, 2000 feet below, lapped silently at the foot of this great escarpment. Away on the distant horizon the ancient volcano of Kulal shot its twin peaks into a cloudless sky. From the opposite shore of the lake, some 15 miles away and strongly lit by the departing rays of the sun, rose one above the other long lines of cliffs—the eastern walls of the Great Rift Valley. Southwards they merged into the northern spur of the Nyeru Massif over 10,000 feet high, which dominates the surrounding country. On the extreme right the northern slopes of that barrier whose other side we had explored the year before led down at first abruptly then more gently to the water's edge. On the crest seemed to stand the northern lip of that ancient crater which we had encountered on the previous expedition and from which so much of the material of which the barrier is composed must have poured forth.

Immediately below the eye followed a grey sandy beach stretching to the right and curving round with a beautiful sweep to the rugged and deeply indented southern coast-line till it rested upon a perfect cone seemingly perched on the end of a narrow promontory of black lava. This evidently was the cone described and photographed by Baker-Beall. The lava was spread over the lower slopes of the barrier like a great black mantle extending to the water's edge where a sudden cooling of the magma in contact with water had given rise to that curious structure associated with such conditions. Here and there it was pierced by lighter-coloured cones and domes, some breached and fractured, others more or less intact. Whilst searching amongst these my eye rested upon a dark hill of no great size on the far side of the lava field and backgrounded by the lower slopes of Mount Nyeru. Just below the summit, which was rather conspicuously coloured red, yellow, and green, I picked up with the glasses a small but very distinct crater: surely this could be no other than Teleki's volcano, and so it proved later to be. But for the strong sunlight which late in the afternoon was throwing it into strong relief it must be admitted that the existence of this comparatively small feature might have escaped my notice as no doubt for the same reason it had escaped that of Cavendish and Baker-Beall.

By this time half of the loads had been carried down to a ledge some 500 feet below, and the weary men were returning to carry down the rest. Darkness overcame us before the unwilling beasts, pushed, pulled, and coaxed, had reached the ledge where we decided to pass the night, and early next morning the descent, which had become easier, was continued. At about 300 feet above the lake the remains of a lake terrace were found, but unfortunately no fossil remains could be found by which it might be dated. Similar shelves denoting levels at which the lake must have stood for considerable periods were noticeable all along the southern shore-line and more especially on the cones of Nabuyatom and Abili Agituk (Plate 7, for which I am indebted to Baker-Beall). On these the most prominent one stands at about 250 feet above the

surface of the water. At the foot of the escarpment the junction with Archaean rocks was again exposed, and some rather curious crush-lines, no doubt the result of rifting movement, were observed in the gneisses. The dip, which is at about 15° to the south-west, causes the older rocks to be brought to the surface of the escarpment near the point where the Mugurr river enters the lake, and from this point northwards the lava cap which gives such a characteristic, feature to the Loriyu plateau thins out and gives place to the softer landscape and less severe modelling associated with the gneisses and schists. After a short pause to allow men and beasts to slake their thirst in the water, which was not so alkaline as I expected, we followed the sandy beach to the mouth of the Neangoil river. An occasional pelican and egret, a pair of Egyptian geese and two pairs of lesser black-backed gulls were put up, and a Goliath heron was so astonished at our approach as to leave a welcome present in the form of a huge fish (*Tilapia nilotica*) which he had only just started to devour. Stints, plovers, curlews, and sandpipers, so common elsewhere on the sandy shores of the lake, were however entirely absent. As was to be supposed the sand was composed of a mixture of volcanic and crystalline grains, and here and there along the water's edge a tinge of mauve occurred owing to the presence of enormous numbers of the most delicate and minute shells (*Fusus?*).

At Neangoil camp was pitched under the welcome shade of a clump of dom palms, which were found growing in considerable numbers in that vicinity. The river here has cut a deep channel in stratified deposits, which were formed as shoals at its mouth from the silt brought down in flood at a time when the lake stood at a higher level. These beds, which are exposed in the banks to a depth of 25 or 30 feet, may be much deeper and would appear to belong to the Upper Pleistocene period, but fossil remains were scarce and insufficient for determining the date with any certainty. About 500 yards up from the mouth a lava flow from apparently high up on the barrier has filled the whole channel and ends in a wall like the foot of a glacier (Plate 8). The lava is a compact warm-grey basalt of not very recent origin.

After a talk with some of the local Turkana, who kept a few goats but lived mostly on fish and the nuts of the dom palms, I set out for the volcano with only three natives and a pack-mule. About 2 miles inland some horizontal deposits attracted my attention, which on examination proved to be shell beds, and from their altitude are probably an extension of the lake terraces which I had seen so clearly exhibited on the lower slopes of the old cones. They were about 250 feet above the present water-level as measured by the aneroid, but there appeared to be similar deposits at a still higher altitude. For an hour or more the way lay through essentially volcanic country, across lava flows with wall-like flanks and of various ages and stages of weathering. A local Turkana had guided me for the first 2 miles, but later thought better of it, and pointing out the best line to take, gave me his blessing and departed. With but one or two checks whilst we sought suitable passages for the pack animals and helped by an occasional suggestion of a track, at 5 p.m. we found ourselves under a red dome-shaped hill. This had the appearance of having been rent in two and out of the resultant fissure a river of lava which extended right across our path and apparently as far as the lake shore had issued. Squeezing our way

through a series of connected cracks, we gained the other side, where the ground was covered with a thick layer of grey cinders which crunched crisply under the feet; here and there were dead and leafless trees and tufts of straw-like grass. The sun was rapidly going down behind us, and though we were still about a mile off I thought it best to seize the opportunity for a photograph of the volcano (Plate 9). With the sinking of the sun great fear fell upon my companions, who scratched a large hole in the cinders under the tree by which I decided to pass the night, wrapped their heads in their blankets, and huddled themselves together for protection. An hour before dawn, when I tried to rouse them, they protested that the devil had entered into their bodies, which ached so that they could not even stand up. Finally I left them, and accompanied only by my Bugishu garden boy, both of us heavily laden, crunched my way through the cinders in the direction of the volcano. At the foot a recent stream of lava some 80 feet wide confronted us. It bore very much the same appearance as the flows on the other side of the barrier, and was found to consist of almost identically the same material (limburgitic basalt). About three-quarters of the way up the south-western face of the hill was a series of four or five open pipes. They were from 3 to 6 feet in diameter, and as they had formed no cones were not visible from more than a few yards off and were in consequence a source of some danger, for they appeared to be bottomless. Looking into them the walls were seen to be red, and scored evidently by the passage of ejecta, and one was reminded of the interior of a factory chimney. Making for a gap in the crest above me, I came upon one of a number of green bushes which were growing on the southern face, a specimen of which has been kindly identified for me by Miss Napier of the Nairobi Museum as *Caparis galeata*. It has a rather distinctive cream-coloured flower which was subsequently found to be quite common amongst the Coral rag of Mombasa Island. The summit was soon gained, the instruments set up, and the position determined by interpolation. The aneroid read 2120 feet, an altitude of 890 feet above the lake-level, which, as mentioned before, I have accepted as 1230 feet above sea-level. The summit was calculated as being 250 to 300 feet above the normal surface of the barrier slope. There were two longitudinal V-shaped rents or fissures some 200 to 300 yards long and up to 20 or 25 yards wide, and approximately the same depth. The whole summit consisted of red and ochre coloured clinker, the colour being most probably due to the sublimation of mineral vapours such as ferric chloride, and of sulphuretted hydrogen. A number of grey volcanic bombs lay scattered about, but they were neither as numerous nor as widely dispersed as those found associated with the eruption of the Likaiyu volcano. Generally speaking the sides of these fissures had the appearance of the inner walls of volcanic craters and were hung with chocolate-coloured clinker suggestive of stalactites. In all probability these fissures had been of considerable depth and through them dust, ashes, and possibly lava had been ejected, but were now choked by the falling in of detrital material. The outer wall or lip of the western fissure presented a broken appearance which I afterwards found to be due to the presence of a number of minor pipes and craters (see diagram). The whole reminded one of the more devastated portions of the battlefields of France. The outer slopes of the volcano were composed of grey cinders generally standing at the natural slope and slipping

7. Abili Agituk, with shelf indicating former lake-level

8. Neangoil river channel filled by a lava flow

9. Teleki's volcano and dust-covered mound from the west

10. Looking north from the summit of Teleki's volcano : Nabuyatom cone middle distance right

11. The sunken craters near Lotarr which may explain the story told by natives to Mr. Cavendish

12. Recent lava flow from an orifi the foot of Teleki's volcano

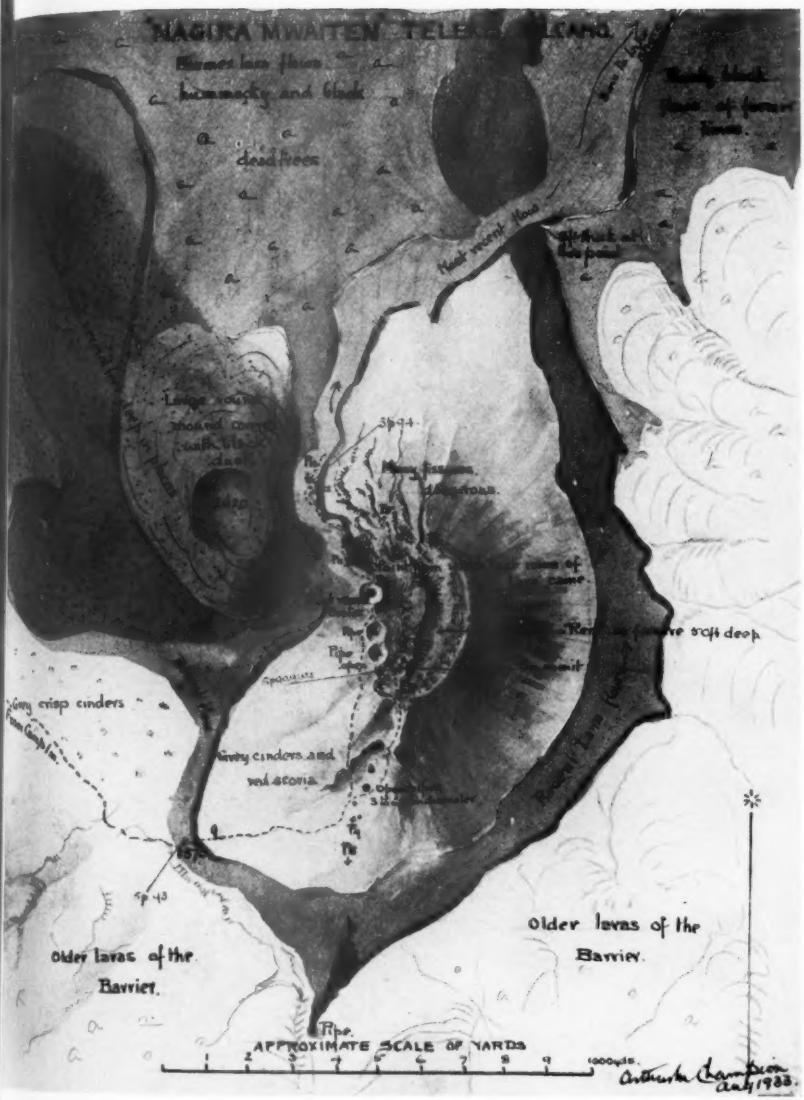
away under foot as one walked. The volcano is called Nagira Mwaiten by the Turkana.

The view from this point was most remarkable (Plate 10). In the dim distance could be seen the many cones of South Island, whilst on the foreshore some 5 miles away was the now familiar and beautifully symmetrical cone of Nabuyatom, which in the Turkana language I am told means "the place of the war horn." From here also it seemed to be at the extreme end of a tongue of lava projecting into the lake. On the left the great escarpment which I had descended the day before frowned down upon the lake, whilst in the foreground lay a field of rugged rusty-looking black lava in which fragmentary cones and curious boil-shaped excrescences of a lighter hue stood up like islands. But the most remarkable feature lay not 500 yards away to the north-west. It was a mound almost as big as the volcano and very nearly as high, but covered with a thick coating of fine jet-black dust. There seemed to be a slight depression on top, but the dust so completely smothered all topographical features that it was difficult to be sure. This dust, lying like a black velvet carpet, extended about a mile and a half to the north-west and was about 800 yards in width. The dust must have been shot out of one of the pipes of the Teleki volcano at a time when the wind was blowing from the south-east, which it does nine days out of ten. Behind me, rising to a height of approximately 3000 feet, were the steep slopes of the barrier, forming a close horizon which blocked further view in that direction. There however lay a point of great interest. From a fissure in the older lavas of the barrier, and about 800 yards south of where I stood, molten lava had recently issued and formed a stream, or, more correctly, two streams completely enveloping the north, east, and west sides of the volcano. Further examination proved that a great portion of the lava field described was formed of magma which had issued from this orifice, and in my opinion it was this flow, then in a molten condition, which forced Teleki to make the big detour to the south and was largely responsible for his and von Höhnel's inability to reach the summit. The western flow, after encircling the dust mound, spread out into two pear-shaped fields, neither of which, as far as was possible to see, extended to the lake. The easterly flow was by far the more extensive and, spreading out a mile or so to the north, seemed to reach the water on a broad frontage. This flow was crossed by a more recent one, which could be detected by its lighter colour and smoother appearance, about a mile or less to the north, but from my position it was impossible to determine the point from which it had issued. While looking for Teleki's camp at Lotarr I saw lagoons enclosed by narrow and curved necks of volcanic material, and it then came to my mind that these might have been active craters until a rise in the lake caused them to be submerged, and so might be explained the story which was told to Cavendish in 1897. Fortunately, Kennaway had been attracted by this phenomenon and had taken a photograph of these lagoons, and to him I am indebted for permission to make use of Plate 11 in illustration of this theory.

I then made my way round the eastern crest, and on the north side was confronted with some long and extremely deep-looking fissures which it seemed best to avoid, so I made a detour to the north and descended on to the recent flow of lighter colour alluded to above. This I found to rest for the most part

on grey cinders, the edges forming quite formidable walls some 6 or 8 feet high. The outer portions or edges were dark and highly vesicular, whilst the centre, which had evidently remained longer in a fluid condition, was lighter in colour, ropy in appearance, and glue-like in texture. It splintered under foot; and as it was riddled with enormous steam cavities, some exploded and others intact like gigantic bubbles, one had to proceed with caution (Plate 12). Some of the chasms were large enough to contain a yoke of oxen and armed with the most formidable looking spiracles of jagged lava. Animal life seemed to be entirely absent, and the silence was only broken by the crackling of the brittle lava around the spot where I stood. My suggestion that my companion should enter one of these exploded steam holes was not well received. In consequence the illustration lacks a comparative standard of size (Plate 14). Henceforward he followed closely in my wake, as slowly and not without some misgivings we traced this flow up to its source. This was found to be a lateral orifice on the north-west face of the cone, to the north and almost under the main crater, which stood 120 feet or more above it (Plate 15). An excellent view of this orifice was obtained from the western shoulder of the depression in which it was situated. From this point we struggled up another 70 feet of sloping cinder to the main crater, which was found to be perfectly circular with inner and outer walls consisting of cinder standing at the natural angle. At the bottom of the crater could be seen the throat of an open pipe also perfectly circular and about 30 or 40 feet in width and, judging from stones thrown in, of inestimable depth (Plate 16). In all respects, except for the formation of the cone and its greater size, it resembled the other pipes. I formed the opinion that the ejecta from these pipes consisted almost entirely of dust, cinders, and clinker, and possibly the bombs seen on the summit and slopes, but that the material of which the lava fields were formed had welled up like boiling pitch with little or no violence from the two orifices to the north and south of the cone. The last issue of magma from the northern one in my opinion took place subsequent to Teleki's visit. Working back to the point of commencement, two or three similar but smaller pipes with surrounding craters were passed. From most of these pipes hot fumes (probably of carbon dioxide and sulphuretted hydrogen) were issuing, but neither in sufficient quantity nor intensity to preclude near approach and inspection. There was no evidence of smoke or steam, but I am inclined to think that the distress I experienced later in the day was due to the heat from below as well as the sun's rays above. The heavy going, the accumulation of geological specimens, together with the numerous impedimenta hung about me may however have caused me to be mistaken in this. The return journey was by the same route and without incident, except that my fresh-water supply had given out, and I was forced for two or three days to drink the lake water, the taste of which I found most nauseating. This however could not mar the pleasure of the invigorating bathe it provided on my return that evening to the Neangoil camp. I most strongly recommended those who followed me to the shores of Lake Rudolf to make ample provision of fresh water.

I am ill qualified to theorize or speculate on the many interesting phenomena which these two journeys present. I cannot resist however an attempt at a reconstruction of the topography of the area, dangerous though it may be.


NAGIKA MWAITEN TELE[KI] VOLCANO.
dead trees
Older lavas of the Barrier.
Older lavas of the Barrier.
APPROXIMATE SCALE OF YARDS
Arthur H. Chapman del. 1933.

13. Sketch of Teleki's volcano by the author

14. Exploded steam cavity in the recent lava flow

15. Largest and most recent crater from the north

16. Open throat of pipe at bottom of the crater

Another glance at the map after the foregoing remarks will, I am certain, suggest the possibility that the long trough running down the centre of the area was at one time covered with a single and continuous sheet of water lying along the narrow floor of the Rift Valley. A study of the rocks of which the barrier is composed shows them to be of more recent origin than those forming the western walls, and a very large crater is placed at about the middle of the barrier. The suggestion is that this crater was once an island, but from time to time ejected such masses of material that it eventually made contact with the land on each side, so dividing the lake into two, cutting off the southern end, which from lack of water supply has dwindled to the Saguta swamp of to-day. The Saguta river may therefore at one time have been one of the headwaters of the Nile. Similar curtailments of the Nile basin have occurred elsewhere. The evidence which tends to support this theory is:

(1) The fact that *Tilapia nilotica* are found in the Saguta swamp and also in Lake Rudolf, whereas they are not found in the other Rift Valley lakes of Kenya.

(2) The fact that the volcanic rocks of which the barrier is composed are not similar to the basalts found resting on the archaean floor or the Turkana grits but are andesites and trachytes, probably extruded during or after the later stages of the formation of the Rift Valley. Unfortunately I have no information as to the nature of the rocks which form the eastern walls of the Rift Valley and the Samburu plateau.

(3) The fact that sedimentary deposits of considerable depth are found not only at the north end of the Saguta valley but some 40 or 50 miles up the course of the river, suggests that the valley was once filled by a sheet of water of much greater volume than could have been maintained by the present drainage area. An alteration in climatic conditions might of course account for this.

The next question which one naturally asks is what gives rise to volcanic activity in this area? In all respects except in size and intensity this latent activity is similar to that which must have existed along the Rift Valley during the middle period of volcanicity. Though the Teleki and Likaiyu volcanoes may be now described as dormant, it would be unwise to presume that they are extinct. Activity may be resumed by future subsidence of the floor of the Rift Valley. A recent example of this process is to be found in the fault line which occurred between Baringo lake and Solai during the earthquake of January 1928. This I had the fortune to examine that same year and found the sinking to amount to 6 feet in certain places. Such a falling in of a portion of the earth's crust must give rise to compression within and consequent disturbance in the magma below, especially if in molten condition and located at no great depth below the surface. This, as we have seen from extruded lavas of the area, possesses an especially high steam content in these regions, due perhaps to some extent to the downward percolation of water either from the lake or the Saguta river. Such magma must be of a highly explosive nature, and if relief is not afforded in another direction volcanicity often accompanied with violence must result. Outlets are afforded along the cracks in the crust of the earth caused by the rifting movement, whether it be due to upheaval, compression or tension, and result in the vents and pipes which we find

following the tectonic lines of the Rift Valley. It is no cause for surprise therefore that we find volcanic cones, such as Suswa, Longonot, Menengai, Paka, and Sillali, thrown up along the floor of the Great Rift Valley, terminating in the smaller but more recently active volcanoes of Likaiyu and Teleki.

Any description of this area and its history would be incomplete without allusion to the tragedy which has so recently befallen the Cambridge Scientific Expedition whereby Dr. Dyson and Mr. Martin in the pursuit of science lost their lives in a storm on Lake Rudolf. That sinister island of many cones has at last been visited, and whilst offering our sincerest sympathy to the friends and relations of the deceased, we can assure Dr. Fuchs that the world of science awaits with interest the result of the labours of the expedition which he has led with such pluck and determination in one of the most inhospitable parts of Africa it has ever been my lot to visit.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: As you know, the subject this evening is Teleki's volcano, at the southern end of Lake Rudolf, which has exercised so many explorers since Count Teleki first discovered it and it was named by his companion after him. Count Teleki went there in 1888, after which the volcano was not visited for some years. An old friend of mine, Dr. Donaldson Smith, a well-known American explorer who received one of the Society's Gold Medals, made two expeditions to Central Africa, and when speaking of his first expedition he told me that from his last camp on Lake Rudolf he had seen Teleki's volcano in eruption one night and its lurid glare lit up the sky away to the south. After that the volcano was only once actually visited, I think, when it was found, to all appearances quiescent, by Captain Welby in 1899. Nobody having seen the volcano since then the idea got about that it had erupted again and disappeared. The whole region is a mass of volcanic lava and débris and, as I say, it was thought that the volcano no longer existed. But our lecturer to-night, Mr. Champion, who is primarily an administrator in the Kenya Colony's Administration and in charge of the Turkana Province, to the south-west of Lake Rudolf, has made it his business for four or five years past to try to solve the mystery of Teleki's volcano, and he is now going to tell us about it.

Mr. Champion then read the paper printed above, and a discussion followed.

The PRESIDENT: Mr. Champion at the beginning of his lecture referred to General Austin, Royal Engineers. It was he who when on survey duty in that region gave a good many of the names to the features of the country. He is, I am glad to say, with us to-night and I ask him to say a few words.

Brigadier-General H. H. AUSTIN: I confess I rise with some diffidence to open this discussion on Mr. Champion's most able and interesting lecture because, as a matter of fact, I have not been to the area which he has so graphically described to us. The nearest point that I ever was to Teleki's volcano was the mouth of the river Turkwel which lies some 50 to 60 miles north-north-west of the region of which Mr. Champion has spoken. Mr. Champion has expressed the hope however that I would say something about Lake Rudolf as I knew it—a good many years ago now. To this request I accede, more particularly perhaps for the reason that we happen to be members of the same house at Clifton College, though not of the same period, as you may probably guess from my white hair. From the College point of view, then, I think I can claim, without any conceit,

that I was the first old Cliftonian ever to penetrate to the wilds of Lake Rudolf and to survey its western shores, now more than thirty-six years ago; and as Mr. Champion has but recently returned from those regions he can probably claim with equal truth that he is the last old Cliftonian ever to have seen Lake Rudolf and to have administered the Turkana Province. Consequently, there is a wide gap of years between us and I feel I am a veritable back-number in all matters pertaining to Lake Rudolf of to-day.

It is more than thirty-three years since I last gazed upon its sombre waters, and then in very depressing circumstances, for the small expedition with which I set out from Khartoum several months previously was then painfully struggling south along the western shores of the lake in the direction of Baringo, on very greatly reduced rations and beset by hostile bands of Turkana. Our feelings then were very different from our elation some three years before when my column of about one hundred and eighty souls from Mount Elgon obtained its first glimpse of Lake Rudolf—on 31 August 1898. For six days previously we had been traversing a desolate, howling wilderness of sand and scrub, where the heat was great and water extremely scarce. It was thus with intense joy that we emerged from that abomination of desolation to behold the waters of the lake shimmering in the early morning sunlight through a gap in the low coastal hills, there about 6 miles distant from the actual margin of the lake. My first view of Lake Rudolf, then, was a matter of great rejoicing among those who accompanied me. My last was the very reverse. We had already suffered much by the waters of Babylon, but still worse times were in store for us before the exhausted remnants of my small party ultimately reached the British post on Lake Baringo—some ten weeks later.

Since those days, as you have heard, enormous changes have taken place, more especially perhaps in the matter of communications. It almost staggered me to hear Mr. Champion say that one can now reach Lake Rudolf by motor car in three days from Nairobi. Before the advent of the Uganda Railway and other means of communication such as motor cars, the journey from that neighbourhood occupied two or three months of solid foot-slogging through very difficult country, to reach the point on Lake Rudolf where I first looked out on it. In those days Nairobi did not, of course, exist; not even a Kikuyu hut marked the site of that flourishing township, the capital of Kenya Colony. It is pleasing to me also to hear, though we have not heard it in the lecture, that my former foes, the Turkana, have turned over a new leaf. They gave me much trouble in 1898 and 1901, but are now, I understand, very good servants of the State; whereas some of the other tribes farther north along the lake, who were, in 1898, in a rather parlous condition, are now, I learn, a considerable thorn in the flesh of the Administration, owing, I understand, to the malign influence of the Abyssinians from whom they have obtained firearms and ammunition—weapons quite unknown among any tribes in the whole of British East Africa thirty odd years ago. It is quite clear, then, that progress and change have taken place in this very remote and forbidding region of the British Empire; and for that progress and change we all owe a deep debt of gratitude to men like Mr. Champion who are cheerfully prepared to devote some of the best years of their lives in introducing the benefits of British rule amongst wild savages in still wilder places.

Although the everlasting hills, the sandy deserts and stony wastes that encompass Lake Rudolf on nearly all sides are perhaps immutable, save for an occasional lapse on the part of volcanoes such as have been alluded to by Mr. Champion, there are considerable fluctuations in the volume of water that constitutes Lake Rudolf. In 1898, for example, numerous small lagoons existed

along the whole of the western shores of the lake, teeming with water fowl; while, in other places, so far had the waters of the lake encroached inland that we saw palm trees disconsolately lifting their shaggy heads above the surface a mile or more from the shore. Three years later the level of the lake was very much lower, owing to the exceptional drought in the previous year when the large river Omo, which you have heard is the only perennial feeder of Lake Rudolf from the north end, had run almost completely dry. The lagoons had almost entirely disappeared, and with them the birds; so even this precarious source of food was denied us in our need. On the western shores of Lake Rudolf no game existed in those days—I do not know whether it does now, for the shores then formed sparse grazing grounds for Turkana flocks and droves of camels. Nevertheless, I was extremely surprised to hear from Mr. Champion, who was in those regions about eighteen months ago, that Sanderson Gulf, which in my day was some 35 miles in length and 10 to 12 in width, had completely dried up. It is very evident therefore that there has been a considerable shrinkage in the size of Lake Rudolf during the past thirty years.

I am afraid I have wandered rather far from the subject of the lecture, and you must forgive me, but, as a matter of fact, we saw nothing of Teleki's volcano. The nearest volcano to Teleki's that I observed at close quarters, except those seen on the islands in the centre of the lake, was Mount Lubur, which is about 150 miles north of the region which Mr. Champion has described. This volcanic mass rises, something like 3000 feet, very abruptly out of the lake and is quite close to it, the rugged rim of its old crater terminating to the east in an immense rock cap little less than 1000 feet in height; while its steep lower slopes were seamed and furrowed to an astonishing extent. But we saw no signs of smoke or steam issuing from it, nor do I remember encountering any traces of lava on the small plain which extended from the base of the mountain to the lake shore, then barely a mile distant.

I must ask you to forgive me for trespassing on your patience so long, but before resuming my seat I would like once again to congratulate Mr. Champion on a very able and most illuminating lecture which, together with the beautiful slides he has exhibited, has carried me back, in spirit at least, to the days of my youth, although my associations with Lake Rudolf were, alas, not always of the happiest description. I want very much therefore, Sir Percy, to associate myself with Mr. Champion in expressing my sincere sympathy with the relatives and friends of the late Dr. Dyson and Mr. Martin, who lost their lives in such tragic circumstances during a big storm on Lake Rudolf. It was a sad end to individuals who had devoted a great deal of scientific work to that treacherous and unholy inland sea.

The PRESIDENT: I now ask Sir Albert Kitson to give us some comments on the geological aspects of Mr. Champion's paper. Sir Albert is a distinguished geologist who has travelled both in West and East Africa and has long experience of those regions.

Sir ALBERT E. KITSON: I have listened with great interest to the lucid description of the country, illustrated with lantern slides, that has been given to us by Mr. Champion. Travelling in such great heat over some of those large areas strewn with big rough blocks of volcanic rocks, promiscuously mixed, must have been most trying, but that did not deter the leader, his natives, or his camels. To do such a large amount of work as was done under difficult conditions and great pressure of time, over areas till then unknown to Europeans and untraversed by them, was a fine performance, and I wish to congratulate Mr. Champion heartily on his having achieved his objects by locating and proving the existence of the suspected volcano, and by having added to our knowledge

of the country in other respects. I look forward with much pleasure to reading his paper when published; also the important petrological description by Mr. Campbell Smith, after his microscopical examination at the Natural History Museum, of the rocks—volcanic and plutonic—that have been collected by the author from these large areas of both young and ancient crystalline rocks.

The PRESIDENT: Mr. Campbell Smith, would you oblige us? Mr. Campbell Smith is head of the Geological Section of the British Museum.

Mr. W. CAMPBELL SMITH: I would like to pay tribute, first of all, to Mr. Arthur Champion as a collector. He has told you what very arduous journeys these have been, but in spite of difficulties he has brought back with him specimens, carefully labelled, of the rocks over which he and his camels struggled and, what is more, he has carefully selected just those rocks which have some bearing on the problems of the relative age of the lavas and, to some extent, of the structure of the country. At the Natural History Museum it is our privilege to receive collections made by explorers from all over the world, many of them Fellows of your Society, but I really think I can say that Mr. Champion is one of the best explorers to collect rocks and I believe also birds and, to some extent, plants.

It is early yet to say very much about the results which will emerge from the study of his specimens when he comes to put together his observations. We have in London a very large collection of the volcanic rocks of East Africa, and we have established some sort of petrographic classification of these, based on the collections made by the late Professor J. W. Gregory. The work Mr. H. L. Sikes has done in Kenya Colony has begun to establish the age relations of some of these lavas, while Dr. J. Parkinson has greatly extended our knowledge of their distribution, particularly in the Northern Frontier Province of Kenya Colony; and now we have the mass of information which Mr. Champion has collected from the Turkana.

It has been quite interesting during the last few years to receive at intervals boxes of rocks, always coming with maps in which their locations are carefully shown, and to note how Mr. Champion has been slowly filling in gaps in the sketch-maps of this province of Northern Turkana. He has in this area shown that there are three different periods of volcanicity. He showed you, first of all, that in going over the Loriyu plateau he got a capping of lavas resting on the old rocks of the basement complex. And then, having crossed the Loriyu plateau, he showed you the barrier cutting off the Saguta valley from the south end of Lake Rudolf, clearly due to a period of volcanic activity younger than the lavas which formed the Loriyu plateau. To this period belong the lavas which fill the Neangoil valley. These are basaltic lavas rather different from those of the Loriyu plateau, and Mr. Champion has shown that there is also a difference in their ages. Lastly, he comes to Teleki's volcano and to the Andrew or Likaiyu volcano from which he has got specimens of the lavas which he can almost date so that we now definitely have samples of the very last periods of volcanic activity in the Colony. I would like to say again how greatly indebted we at the Museum are to Mr. Champion and to others like him for collecting so carefully under such trying and arduous conditions.

The PRESIDENT: Dr. Worthington has particularly studied the question of lake-levels in the Rift Valley. I will ask him to add a few words.

Dr. E. B. WORTHINGTON: I am very glad of this opportunity of adding a word of appreciation of Mr. Champion's excellent paper. There are a number of points which interest me deeply and I look forward some time to discussing them with Mr. Champion.

The President has referred to the question of lake levels. Two or three years

ago when my wife and I had an opportunity of looking at both sides of Lake Rudolf from the water in the latitude of Central Island, we noticed, and subsequently confirmed by climbing up the shores, high-level beaches on both sides of the lake which turned out to be about 250 feet above the present water-level. In one of Mr. Champion's photographs, taken near the south end of the lake, he pointed out an obvious high-level beach, which he told us was 250 feet above the lake, cutting into the side of a volcano. This means that on the east and west shore about half-way up the lake and again at the south end there is an old and pronounced high-level beach about the same height, which indicates that since the lake was at that high level the land has remained fixed. We have here something definite to go on in working out the ancient history of that region, and I am hoping that when Mr. Fuchs and the rest of his party return to this country in a few weeks' time, they will have similar evidence from the north end of the lake to confirm this ancient high level, when Lake Rudolf poured its waters into the Nile system.

Mr. Champion has given us a lucid explanation of this curious mountain formation: the two sides of the Rift Valley with a line of volcanoes crossing from one to the other to form the cross-bar of the letter H. The line of volcanoes thus forms a mighty dam and the waters on either side, occupying the floor of the Rift Valley, are separated. Hence all the creatures in those waters are isolated from each other. Such damming of the Rift Valleys by volcanoes has had a very pronounced influence in the past on the aquatic life of the continent. The south end of Lake Rudolf is not the only example. One might mention, for instance, the famous Mountains of the Moon, the Mfumbiro range, which dammed part of the upper Nile not so very long ago and slopped the waters in the opposite direction into the Congo. Biologists as well as geographers and geologists must be indebted to Mr. Champion for elucidating such matters in a wild and arid region.

The PRESIDENT: The discussion has been extraordinarily interesting, but the hour is late and we must now close. It is evident from what we have heard and seen on the screen that Mr. Champion has done a very valuable piece of work indeed; it is a definite achievement for which he has worked for some years. We cannot congratulate him too heartily on his success in dispelling the mystery of Teleki's volcano. All the photographs we have seen appear to identify it fully, and it is precisely in the same position in which Teleki recorded having seen it. It seems to me there can be no further question as to its identity, and Teleki's volcano will remain on the map where he put it, but with much additional information in regard to the country round about it, for which we have to thank Mr. Champion. As to the photographs that the distinguished geologists who have spoken called so beautiful, we have just seen during Christmas week some marvellous photographs of the Himalaya and other beautiful scenery, but from the picturesque point of view the pictures at which we have been looking this evening portray the most ghastly type of country that one can imagine. From the geological point of view of course they were splendid. But what country to travel in!

Well, ladies and gentlemen, I can only say one word more before I close. General Austin, at the close of his remarks, has made brief mention of the sad tragedy which befell the Fuchs Expedition, in the loss of two of their party, Dr. Dyson and Mr. Martin. I was referring to the subject in conversation with Mr. Champion at dinner. He has the latest information, of course, and there is clearly no doubt whatever that they were drowned in getting from the south island to the mainland. One might cross that 4-mile stretch of water a hundred times without incident, and then at the hundred and first time come to grief.

All expeditions must take such risks; the leader, Mr. Fuchs, will soon be in England, and we hope to see him here later on and hear his account of the expedition.

Finally, I would remind you that Mr. Champion in addition to his geological work collected steadily all the time he was out and has, I understand, made a fine collection of birds which have gone to the Natural History Museum. There are also his geological specimens which Mr. Campbell Smith has told us about and a great number of botanical specimens. One can hardly imagine a small expedition such as his effecting more and working more thoroughly than he has done on this occasion. I ask you to join me in thanking him warmly for his interesting and most important lecture.

THE MOVEMENT OF DESERT SAND: *A paper read at the Afternoon Meeting of the Society on 11 February 1935, by*

MAJOR R. A. BAGNOLD

MANY papers about sand-dunes have been read before this Society, and in a recent book[1] Dr. Vaughan Cornish has summarized the results of his many years of careful observation on the subject of sand-waves, or what are perhaps better described as repetition phenomena. I am sure all the writers will agree that although the visible appearance of sand-dunes has been faithfully detailed, yet there is an unsatisfactory element about it all, in that we do not seem to be any nearer to a real explanation of a single one of the many curious phenomena exhibited by blown sand.

It seems to me that there are two sets of problems to be solved, and that before any of the fascinating questions connected with the shape and regularity of the great desert sand-dune systems can be tackled seriously we must solve the more fundamental problem of why and how sand accumulates at all, instead of scattering haphazard over the country. In other words we must try and find out the mechanism of the interaction of the wind with the individual flying sand grains. Only after that can the second set of problems be tackled, namely the interaction of the shape, size, and repetition distances of the dunes themselves with the sand-driving and sand-depositing wind, and therefore with the equilibrium conditions which must give rise to that shape, size, etc.

In the following paper I shall confine myself to the first set of problems, the mode by which sand grains are driven across country, and the cause of their accumulation in certain places only. I shall describe a hypothetical mechanism which may or may not be afterwards found by field experiments to be true, but which seems to be possible and to be capable of explaining many observed facts, at any rate in the deserts with which I am familiar.

But I must first point out a confusion of ideas which has come about owing to a failure in many cases to define just what is meant by sand and to distinguish it from dust. When the wind rises over an arid country where loose particles of rock or dry humus, clay, etc., lie exposed on the surface it picks up some of them and drives them along with it. Fine particles are carried up by turbulent currents of stormy wind, sometimes to heights of many thousands of feet. In this way dark clouds can be produced which are called indiscriminately sand-storms or dust-storms. At the same time that this cloud is produced high in the air other particles are seen to drive along near the ground and to accumulate on the ground into drifts in the wind-shadows behind rocks, bushes, etc. These are the particles which accumulate in the open desert to form the dunes. They alone should be called sand. The particles composing the high cloud are dust and their size is very small indeed. When the wind abates they fall evenly over the country and have no power of accumulation.

It is unfortunate that the great majority of observations on blowing sand have naturally been made where the dunes are accessibly located near human settlements, where water is available, and whither transport runs—on riverine

[1] 'Ocean Waves and Kindred Geophysical Phenomena,' with additional notes by Dr. Harold Jeffreys, 1934.

dunes in Europe, or near the lower Nile for instance. Human settlements in these areas are associated with the dust of tilled lands, river mud, and village refuse, and so the actual phenomenon of sand-driving by a wind has been somewhat obscured by the accompanying dust whose smoky appearance in the air is in general far more easily seen than are the larger and fewer sand grains. Thus it has been taken for granted to a large extent that the turbulence of the wind, so well shown up by dust-clouds, is the lifting agency alike of sand and dust.

The sand grains are composed of hard rock, usually quartz. I have analysed for size a good many samples of sand taken from widely separated parts of the Libyan Desert, from dunes, whalebacks, sand-sheets, drifts, etc., and also from the permanent sand of the desert floor. The range of grain size is very narrow in comparison with that of small particles in general. The largest grains have a diameter of 2 millimetres; the vast majority of grains have

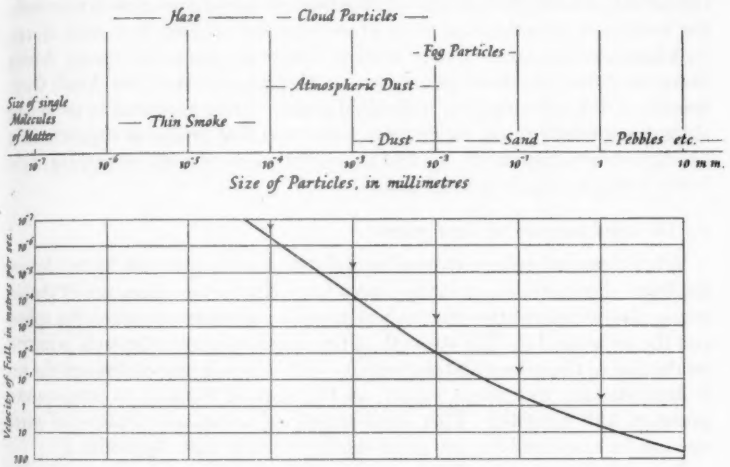


Fig. 1

diameters between 0·8 and 0·08 mm.; less than 3 per cent. of any sample by weight was found to consist of grains less than 0·04 mm. in diameter; and from a microscopical examination of this residue I found that the proportion of grains of diameter less than 0·02 mm. is negligible. Thus, considered in ratios of greatest to smallest, sand occupies a range of about 50, whereas the whole range of size from largest sand grain to smallest particle of dust is well over 1,000,000. And of the range of 50 occupied by sand, the main bulk occupies but 10. Fig. 1 gives a rough idea of the position occupied by sand in the general range of small particles.

In the far interior of the Libyan Desert we have therefore a possible experimental field where there is no dust and where the sand can be very clearly defined. Not only are the dunes themselves uncontaminated by vegetation, salts, dust, or moisture, but the phenomenon of sand transportation, or sand-driving, *i.e.* the pure interaction of wind and sand, can be observed by itself.

The whole appearance of the air during a sand-driving wind is very different from the pictures one sees of vast rolling masses of dense cloud in 'Iraq, the Indus Valley, the Sudan near Khartoum and elsewhere, which are erroneously spoken of as sandstorms. In the Libyan Desert, except during a severe storm, the visible cloud rarely rises higher than one's shoulders, and the sky above is almost clear. The cloud may be very dense, the crests of dunes may alter shape as one watches, the whole surface may be removed from round one's feet as one stands, but the top of the cloud remains within a metre or so of the ground as a clearly defined surface: a moving carpet. The grains composing it are large. It is a common and painful experience for grains of 1 mm. diameter to strike one's face. And the wind during such a storm is remarkably steady; it seems to blow almost without gusts or large-scale turbulence.

At first sight it may seem an easy thing to find out how this sand moves and how it is deposited. One has but to go and look. But it is not easy. One cannot see, or even photograph with the highest-speed cine-camera now made, the motion of an individual grain of average size moving in a wind of, say, 30 kilometres per hour. I once tried to follow the grains by eye by driving down wind over the desert in a motor car keeping pace with the cloud. Occasionally I did catch sight of individual grains. They appeared to be gliding along horizontally in the air entirely without visible means of support. How are they in fact supported? To find an answer we must know something of the forces acting on the individual grains.

1. *The wind pressure on sand grains*

When a smooth sphere moves through the air it is acted on by two forces: the force of gravity, downwards; and a force due to the resistance of the air, acting always against the direction of relative movement between the sphere and the air around it. The strength of this wind-resistance depends primarily on the size of the sphere and the velocity with which it moves through the air; it depends also, to a lesser extent, on the state of the air: its temperature, pressure, and humidity. This wind-resistance acting on a sphere of given size can be calculated for any given relative velocity (see Appendix I).

But even if it were possible to measure this wind-resistance in the case of a single sand grain, such measurement would not be of much use. A more useful quantity to deal with is the ratio of the force of the wind-resistance to the force of gravity acting on the grain. I will call this ratio the "susceptibility" of the grain. The diagram in Fig. 2 shows the susceptibility of ideal smooth quartz spheres of various sizes when they move through the air with various relative velocities (see Appendix I for data used for the construction of this diagram). On this Susceptibility Diagram the velocity corresponding to unit value of the susceptibility should be noted particularly. For this velocity the wind force is equal to that of gravity. It is called the Terminal Velocity of the grain. If allowed to fall through still air the grain will gather speed. As it does so the wind-resistance acting on it will also increase until finally the latter just balances the force of gravity. There is no further acceleration, and the grain thereafter falls with constant velocity. It cannot fall faster than its terminal velocity. Conversely under steady conditions a vertical upward current of air of greater velocity than this is needed to maintain a grain

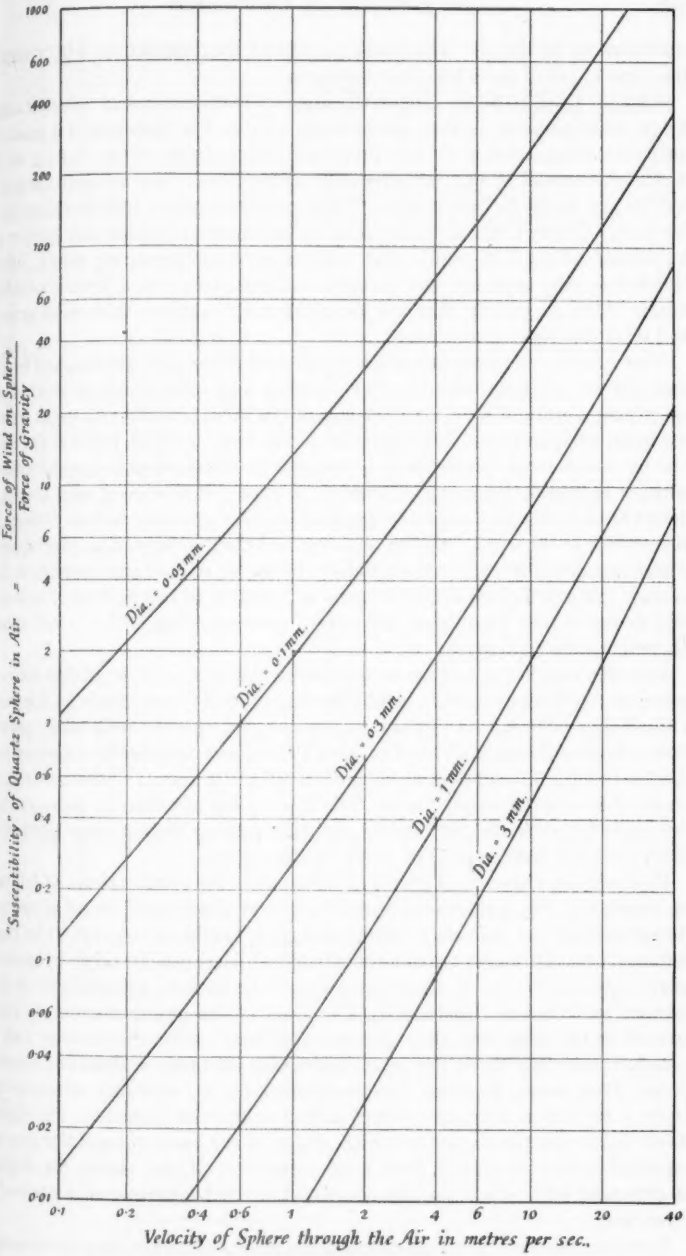

"Susceptibility" of Quartz Sphere in Air = Force of Wind on Sphere / Force of Gravity
1000
600
400
200
100
60
40
20
10
6
4
2
1
0·6
0·4
0·2
0·1
0·06
0·04
0·02
0·01
Dia. = 0·03 mm.
Dia. = 0·1 mm.
Dia. = 0·3 mm.
Dia. = 1 mm.
Dia. = 3 mm.
0·1
0·2
0·4
0·6
1
2
4
6
10
20
40
Velocity of Sphere through the Air in metres per sec.

Fig. 2

continuously in the air. The lower portion of the diagram in Fig. 1 shows the rates of fall of particles of various sizes.

Another point to be noticed on the diagram is the enormous value attained by the susceptibility in the case of small grains. For instance, if a grain of 0·03 mm. diameter is suddenly projected into a stream of air flowing at 15 metres per second or 54 kilometres an hour the force of the air upon the grain will be 500 times its own weight. These tiny dust grains will therefore conform very closely to the movements of the air-stream in which they happen to be carried. They will collide with solid objects comparatively rarely, being checked as they approach and diverted with the stream as it flows round the object. Microscopically they are therefore much sharper than sand grains, and show few signs of rounding.

Now to apply all this to actual sand grains, which are not spheres, and which may not be perfectly smooth. The simplest and most practical method of specifying a grain of sand is by the size of the holes in a sieve through which the grain will just pass. It is in general a very loose method, but it is the only one by which large quantities of grains can be obtained to one specification without elaborate apparatus. It cannot be expected that even with rounded desert sand a collection of grains specified by sieve-aperture will be uniformly susceptible to the wind. We can however find the diameter of an ideal sphere whose susceptibility will make it behave in the air in the same manner as the average grain in a given sample of sand of a certain sieve-aperture. I will call this diameter the "Equivalent Diameter" corresponding to the actual mean diameter of the sand grain.

For velocities below and up to the terminal velocity, the time taken for real grains to fall through a given height can be found very accurately by allowing a small shower to fall on to a slowly rotating disc covered with sticky paper, from a hopper which is allowed to open by a trigger actuated by a cam on the disc, so that the shower of grains begins its fall at the instant a fixed zero radius on the disc is immediately below. The time of fall can then be measured by the angle between the zero radius and that passing through any particular grain (which is held in position by the sticky paper).

By dropping a shower of grains of mixed sizes the relative times of fall can be measured. Fig. 3 shows the sizes of grains of desert sand found at various time-points on the disc after falling through a height of 109 cms. The continuous curve represents the theoretical time which should be taken by smooth quartz spheres of various diameters to reach the bottom, as calculated in the manner indicated in Appendix I. The sizes of the grains themselves were arrived at by measuring their greatest and least visible dimensions with a microscope as they lay on the paper, and taking the mean of these two dimensions. This mean diameter was multiplied by an arbitrary shape-factor of 0·75 to turn it into the corresponding equivalent diameter. The figure shows fairly well the degree to which grains of the same general size may be expected to vary as regards their wind-resistance. It also shows the degree of closeness with which one can calculate the wind-resistance of a grain of a given size.

For observations of the wind-resistance at velocities higher than the terminal velocity, the grains can be shot vertically upwards into still air, and the height

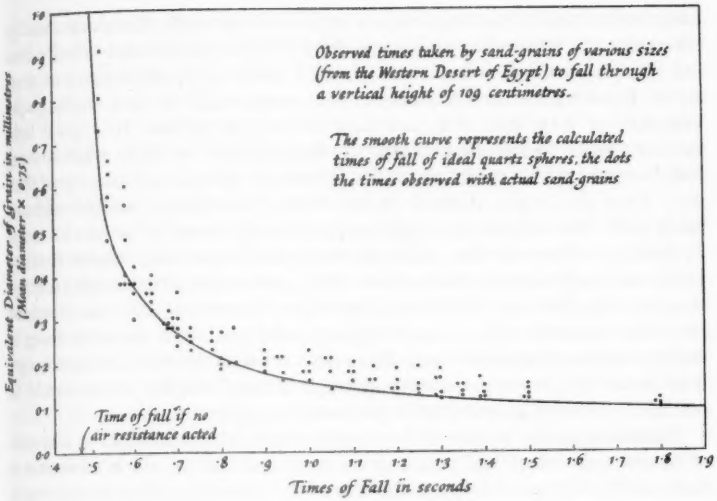

Observed times taken by sand-grains of various sizes (from the Western Desert of Egypt) to fall through a vertical height of 109 centimetres.
The smooth curve represents the calculated times of fall of ideal quartz spheres, the dots the times observed with actual sand-grains
Time of fall if no air resistance acted
Equivalent Diameter of Grains in millimetres (Mean diameter × 0·75)
Times of Fall in seconds
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
·4
·5
·6
·7
·8
·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6
1·7
1·8
1·9

Fig. 3

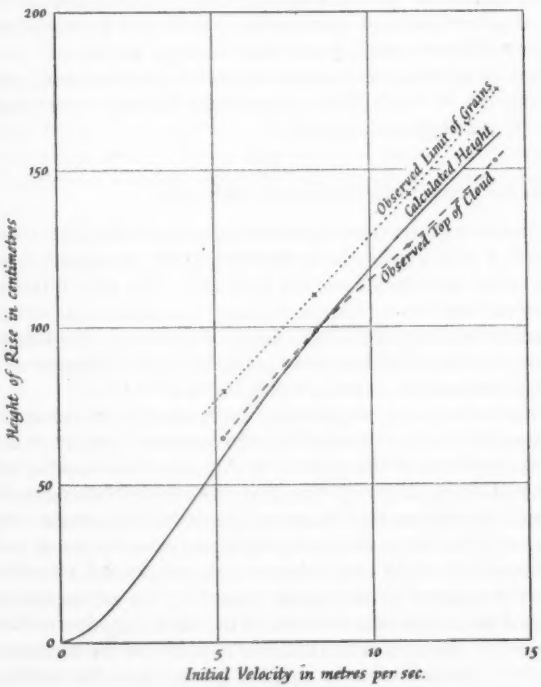

Observed Limit of Grains
Calculated Height
Observed Top of Cloud
Height of Rise in centimetres
Initial Velocity in metres per sec.
200
150
100
50
0
0
5
10
15

Fig. 4

measured at which they come to rest before falling again. Here care must be taken that the method of producing the known initial upward velocity does not also produce upward currents of air. I have used a spring gun of short stroke fitted with a narrow plunger, and compressible in four stages giving velocities of 5·25, 8·2, 11·2, and 14·0 metres per second. In a good light against a black background a small shower of grains, invisible while moving fast, becomes visible to the eye at the instant the grains reach the top of their rise. Thus the height attained by the bulk of the grains can be estimated fairly well. The maximum height reached by any of the grains can be found by holding a sheet of oiled glass over the gun at increasing heights until no grains are caught on the oiled surface. Fig. 4 shows the actual heights reached by grains of a diameter of 0·4 mm. (equivalent diameter 0·3 mm.) as measured by a sieve-aperture of 0·4, which appears to be practically the same thing as the mean of the greatest and least dimensions as measured with the microscope. The figure also shows the corresponding calculated heights which should be reached by smooth quartz spheres of diameter 0·3 mm.

Summarizing the results of my experiments: it appears that of a sample of quartz sand which will pass a given sieve-aperture or whose mean size is measured by the microscope, a fair idea of the behaviour of the grains can be gained from the calculated behaviour of a smooth sphere of a certain equivalent size. If the equivalent diameter of an average grain is required, the mean diameter, equal to the sieve-aperture or to the mean measured dimensions, must be multiplied by a shape-factor of about 0·75. If the equivalent diameter of those grains which have a minimum air-resistance is required, a shape-factor of about 0·85 can be used. There seems to be nothing mysterious about the behaviour of a sand grain in the air.

2. *How are the grains in the sand-cloud supported?*

We are now in a position to examine more critically the facts about the low-flying cloud of pure sand, with a view to seeking the agency by which the grains are raised into the air and are kept aloft. The view hitherto accepted is that they are kept up by the same agency that raises dust-storms, namely the upward components of the turbulence of the wind. Can this account for the fact that in a very moderate wind grains of a mean diameter of 1 mm. are found flying high enough to strike one in the face?

We have seen that for a grain to be carried up into the air it must be subjected to an upward air current greater than the terminal velocity of the particle. This is not quite true if the grain is at the same time moving horizontally through the air at a speed greater than that with which it falls vertically through the air. But if we suppose that the grain is supported by upward eddy currents it will remain in the air for an appreciable time, several seconds, and the only horizontal motion it could have relative to the air around it would be due to the internal changes of air movement caused by the eddies themselves. As these internal air movements must be of the same magnitude whether horizontal or vertical, the argument still seems to hold that the necessary supporting upward air currents must be equal or greater than the terminal velocity of the grain.

Upward currents do in fact exist in an ordinary wind, and are due to eddies, in the form of rotating cylinders or discs, as it were, of air moving along with their axes inclined to the vertical. These, together with similar eddies in other planes, all in haphazard sequence, give rise to the common gustiness of the air. The velocity of rotation of these eddies is rarely greater than the general wind velocity, and usually very much less. The linear dimensions of the eddies are most frequently from 2 to 8 metres, but may reach 50 to 70 metres (Sir Napier Shaw, 'Meteorological Calculus,' p. 144).

I can find no evidence that in flat, open desert country sand-driving winds are accompanied by unusual gustiness. On the contrary, as previously stated, it has always been my experience that whenever sand is driving the wind is unusually steady. And yet the terminal velocity of an average grain of sand of mean diameter 1 mm. is 7 metres per sec. or 25 kilometres per hour, so that it requires an upward wind current of about this strength to support it. It is very doubtful if such violent upward currents are present within a metre or so of the ground. One has only to watch a puff of smoke from a small fire, or, as Mr. Beadnell has pointed out to me, to see an uprooted *aqul* bush, or one's precious sponge drifting down wind over a smooth, flat plain, to realize how insignificant are then the internal air currents compared to the main steady sweep of the wind.

It would seem natural too, if the sand-cloud really were maintained above ground by the upward currents of eddies, and if we take the observed dimensions of the eddies to be the same as in ordinary countries, from 2 to 70 metres across, that the appearance of the cloud would be a series of high, uneven plumes of the same order of height as the eddy dimensions, separated by wide gaps. Instead of this, a strangely even cloud of flying grains, rarely higher than 2 metres and usually lower than 1 metre above the ground, glides over the country like a carpet, apparently driven along by an almost gustless wind.

But if turbulence seems unlikely as an explanation, what other forces can possibly keep these large, heavy grains up in the air?

3. *Bounce*

It occurred to me some time ago to seek a solution by denying that any appreciable upward air currents exist at all, and then trying to construct a hypothetical sandstorm with a wind the velocity of whose internal turbulence is small compared with the velocity over the ground.

Let us assume the commonest kind of desert surface: one composed of rounded pebbles. Assume also that the wind velocity is uniform at all heights down to a millimetre or so above the ground. Now suppose that a spherical grain of quartz sand is somehow lifted just off the surface and set in motion by the wind so that it glides over the surface with a velocity approaching that of the wind. (H. Jeffreys has pointed out that a grain could be so lifted by the effect of the differences of pressure due to the differences of wind velocity above and below it, provided that most of the increase in wind velocity from zero to its measured value occurs within a surface layer of the same order of thickness as the diameter of the grain (*Proc. Camb. Phil. Soc.*, vol. xxv, pt. iii, 1929).) The grain will eventually strike a pebble. Suppose it does so at a

point on the pebble where its surface is inclined at 45° to the horizontal. If the elasticity is perfect the grain will bounce vertically upwards with undiminished velocity.

If we adopt the device of superimposing on everything—ground, air, and sand grain—a velocity equal to that of the wind but in the reverse direction, the relations between all these objects will remain the same, but to an observer at rest in the now stationary air it will appear as if the sand grains were being fired off from the ground at an angle of 45° (the horizontal and vertical velocities being equal). The trajectory of the grain can now be calculated by approximate methods, as in gunnery. This trajectory will trace the movement of the grain backwards through the air. To find the real path relative to the ground one has but to move each point in the trajectory down wind through a distance equal to the main drift of the wind during the same elapsed time.

Trajectories of grains of different sizes after starting vertically upwards at a velocity of 10 metres per second into a horizontal wind of 10 metres per second (36 kilometres per hour).

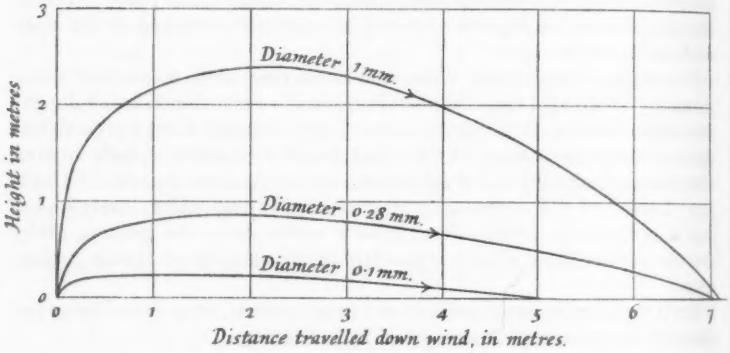


Fig. 5

In Fig. 5 the calculated real paths are shown of grains of diameter 1, 0·28, and 0·1 mm. after they have started vertically upward with a velocity of 10 metres per sec. (36 kilometres per hour) into a horizontal wind of the same speed. The approximate constancy of range of travel is very striking if it is remembered that the susceptibility of the smallest grain is fifty times that of the largest. Of course only a very small proportion of the grains will succeed in hitting a pebble surface inclined at just the proper angle to make them reach this maximum possible height, and only a few real non-spherical grains will hit a pebble fair and square without losing much of their linear momentum by starting to spin. A great many grains, too, will fail to strike a pebble on its meridian, and will therefore come off sideways with a velocity component at right angles to the vertical plane of the wind.

By varying the initial upward velocity other trajectories and other real paths can be calculated. The following table shows details of the behaviour of an ideal spherical quartz grain of diameter 0·28 mm. rising vertically into a

uniform horizontal wind of 10 metres per sec. (36 kilometres per hour) with various initial velocities.

Vertical velocity component in metres/sec.	10	6	4	2	0·60
Maximum height reached, in metres	0·87	0·44	0·26	0·10	0·012
Time of flight, in seconds	0·87	0·62	0·45	0·26	0·1
Final downward vertical velocity in metres/sec.	2·3	1·9	1·6	1·1	0·42
Final horizontal velocity	9·75	9·5	9·25	8·1	5·3
Distance travelled relative to the air in metres	1·6	1·5	1·4	1·2	0·70
Range down wind relative to the ground in metres	7·1	4·6	3·1	1·6	0·34
Angle of impact (inclination to horizontal)	$13\frac{1}{2}^\circ$	$11\frac{1}{2}^\circ$	10°	$7\frac{1}{2}^\circ$	$4\frac{1}{2}^\circ$

In general there will also of course be a horizontal component of velocity forward or backward when the grain rebounds, but its effect, except in extreme cases, is slight. For example, by adding a backward horizontal velocity to the grain equal in all cases to the vertical component so that it rebounds backwards at an angle of 45° instead of vertically upwards, the height of rise is reduced by 25 per cent., the range by 18 per cent., and other figures by not more than 9 per cent.

The sustained high values of the final velocity even for very low initial velocities of rise should be noted. A grain will reach a velocity of more than half that of the wind even though it starts upward with only sufficient speed to reach a height of 1·2 cms. The low, flat paths of all but the largest grains should also be noted. They are quite flat enough to give the effect to the naked eye of a continuous horizontal motion. Lastly, it will be seen that the ratio of range to final horizontal velocity drops rapidly as the initial upward velocity is decreased.

Now all this may seem to have little to do with reality. Still, the possibility of this bouncing motion of the grains can to some extent be tested at home if we adopt the same device of superimposing a negative horizontal velocity equal to that of the wind on all external objects: ground, air, and sand. The relation between these objects will of course remain unaffected. To the observer everything will appear as if he were driving down wind in a motor car at the same speed as the wind. The ground will be rushing backwards and the sand grains will be dropping on to it practically vertically through still air.

I represented the moving ground under a fixed column of still air by the surface of horizontal rotating disc. Several discs were used, each with pebbles and other obstructions gummed on to its surface to imitate various types of ground. Sand was dropped vertically on to the disc as it turned, so that the grains as they hit the fast-moving pebbles were driven off in various trajectories at a tangent (and also of course in other directions deviating from the tangent). In this experiment it should be remembered that the trajectories are not the same as the real ones which are relative to the ground, but represent the travel backwards relative to the air. The real range is, as before, merely a

matter of calculation. The height reached, being measured at right angles to the fictitious superimposed velocity, remains the same as the real height reached if the ground was stationary and the air moved over it.

In one series of experiments the grains were captured on vertical strips of sticky paper hung at various distances from the point of impact. In others the grains were allowed to fall to the ground and were collected on sheets of oiled glass which, with the proper lighting, picks out even the smallest grains very clearly.

Fig. 6 shows the calculated trajectories of ideal spherical grains of quartz of diameter 0·3 mm. after being struck by surfaces inclined at various angles and moving horizontally at a speed of 12·5 metres/sec. (about 45 kilometres per hour), together with the highest experimental points at which real grains of desert sand were found when the disc was spun at this same speed. I would

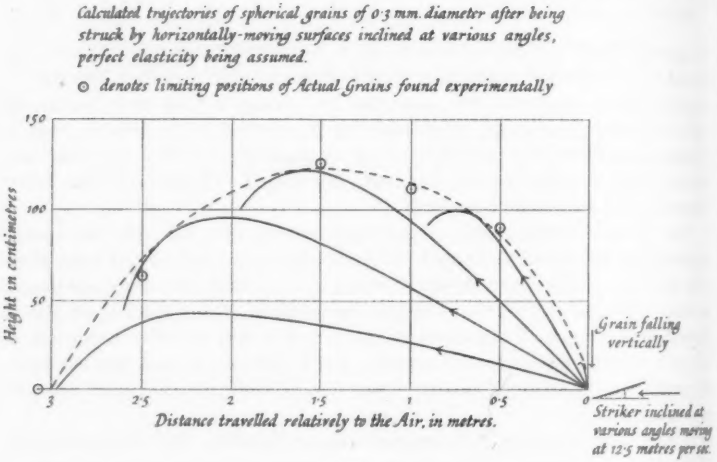

Calculated trajectories of spherical grains of 0·3 mm. diameter after being struck by horizontally-moving surfaces inclined at various angles, perfect elasticity being assumed.
⊙ denotes limiting positions of Actual Grains found experimentally
150
100
50
Height in centimetres
3
2·5
2
1·5
1
0·5
0
Distance travelled relatively to the Air, in metres.
Grain falling vertically
Striker inclined at various angles moving at 12·5 metres per sec.

Fig. 6

point out that in this figure the agreement between theory and experiment is not quite as close as it looks, because the curves were calculated for "equivalent spheres," *i.e.* for the average grain, whereas the grains which would be found to fly farthest in practice would be the exceptional ones. Thus, if elasticity were perfect, the limiting positions found experimentally ought to be a little farther out. Still, these experiments show that at least some sand grains are in fact almost perfectly elastic, and do follow fairly closely the paths calculated from general aerodynamical data.

Digressing for a moment, apropos of these spinning disc experiments, it seems that the grains of eolian sand accumulations have become rounded not, as is commonly thought, by continually striking one against the other in the air, but by striking rocks, pebbles, or other grains on the ground, and that the velocity of the impacts has been practically that of the wind and is therefore more or less of a known quantity. (The chance of an impact between grains in mid-air is negligible compared with the certainty of a grain hitting the

ground a second after it has risen.) I found that with the imitation 45-kilometre wind in the experiment considerable shattering took place among grains of a sample of sand from beds at Charlton, near Greenwich, whereas there was no shattering whatever when using sand from the Libyan Desert. The small shattered fragments were seen to cover the oiled glass plates near the disc, and could be collected and examined microscopically. Both samples were the same size and appeared under the microscope to have the same degree of rounding. Here is a possible point worthy of investigation in connection with the question of how the grains of any particular sand reached their present shape and size.

To return: there can be little doubt that a bouncing motion of sand grains can and does occur. The question whether, as I think, it is the normal mechanism of eolian sand transportation, or whether turbulence is the chief factor, must await experiments in the field. Meanwhile, as the hypothesis seems to have some interesting consequences, it will be well here to give a clear picture of the supposed motion as we should see it if it could be photographed by a cine-camera even more rapid than any yet made.

We begin with a background of dust whose largest grains are probably less than 0·1 mm. in diameter (with a terminal velocity less than 0·6 metres/sec.) and whose average grains are far smaller. This dust is kept aloft by such turbulence as may exist. The larger of these dust grains occur only near the ground and the size gets less as the height increases. Superimposed on this we have a low-flying cloud of sand grains of diameters between 0·1 and 1·2 mm. (or perhaps bigger in high winds). The upper limit of this cloud is about 2 metres and its main bulk in moderate winds reaches about half a metre above the ground.

The grains of this sand-cloud move as follows: A horizontal or nearly horizontal velocity approaching that of the wind is imparted to the grains soon after the upward suction of the air at the ground-level surface of discontinuity lifts them off the ground. They strike the nearest hard object and are deflected upwards. They may rise to any height up to a maximum determined by the wind velocity and by their size. Once in the air they are exposed to the wind, which drives them in long, flat trajectories whose maximum range again depends only on the wind strength and the grain size. They reach the ground again at a flat angle (increasing in steepness with the size of grain). On reaching the ground they may either strike another hard object and bounce off once more, or they may disturb similar grains at rest on the ground causing some of them to splash up a short distance into the air, and in their turn to be driven down wind and to strike other hard objects.

4. *Some consequences of the hypothesis. The effect of the sand-cloud on the ground surface. A possible origin of the normal ripple-mark*

Hitherto we have assumed the surface objects—pebbles, etc.—to be so large compared with the flying grains that they remain unmoved by the continuous low-angle bombardment to which they are subjected during sand-driving.

Let us now consider surfaces composed of smaller and smaller pebbles until a diameter of from 4 to 1·2 mm. is reached. These pebbles are no longer

immovable. According to experiments carried out by Sokolow (quoted by Harold Jeffreys, *op. cit.*) the strength of wind required to move pebbles of 2 mm. diameter is about 60 kilometres per hour, a strength rarely met with in the Libyan Desert, which is an exceptionally calm place meteorologically. But during normal desert winds they will be rolled or pushed along the ground very slowly by the impact of countless smaller grains as they descend out of the sand-cloud. In other words, a grain may be given a slow ground motion by a far gentler wind than is required to raise it into the sand-cloud. This applies both to small pebbles and to the sand grains themselves.

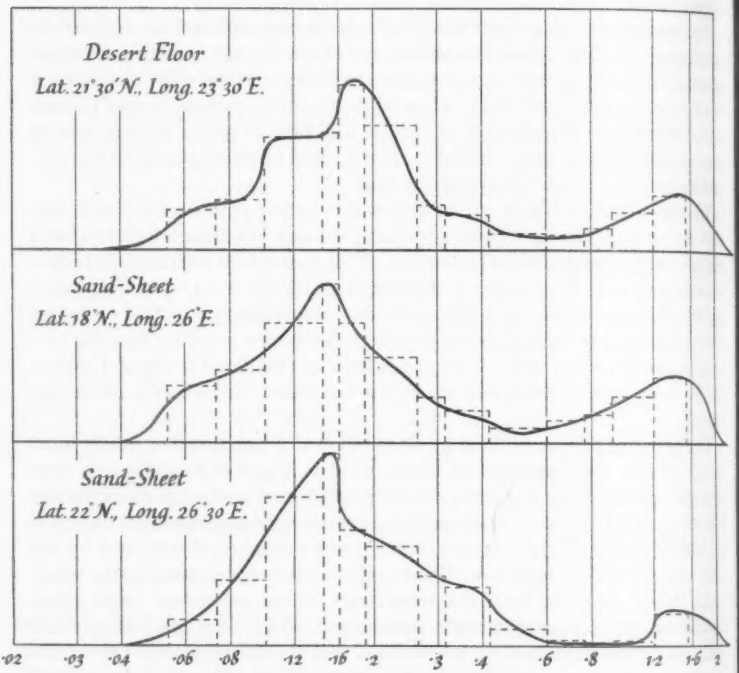

Desert Floor
Lat. 21°30′N., Long. 23°30′E.
Sand-Sheet
Lat. 18°N., Long. 26°E.
Sand-Sheet
Lat. 22°N., Long. 26°30′E.
·02 ·03 ·04 ·06 ·08 ·12 ·16 ·2 ·3 ·4 ·6 ·8 1·2 1·6 2
Diameter of Grains in millimetres

Fig. 7

Fig. 7 shows "distribution curves" of three samples of normal flat desert floor collected haphazard from spots 500 kilometres apart. Here, if the whole area under the curve is taken as 100, then any small area enclosed between any limit of size chosen along the bottom scale shows the percentage weight of sand of this size present in the sample. The method of construction of these curves is given in Appendix II. The presence of the pebbles in each sample is well shown by the humps on the extreme right of each curve. The pebbles exist in great quantities in the desert, and numerous examples of their creeping motion can be seen. They are often found collected on the lower windward slopes of isolated barchans up which they have doubtless been driven until

the angle becomes too steep for them to climb up any higher. They are found, too, composing the bulk of the crests of giant ripples[1] for whose formation they seem indeed to be essential.

Now let the sand-cloud pass on to a more mobile area where the biggest ground particles are sand grains of, say, 0·8 mm. diameter. These, according to Sokolow's figures previously quoted, should just be moved by wind action alone when the wind reaches 36 kilometres per hour. Suppose that these are mixed, as they normally would be, with a wide range of still smaller grains. Fig. 8 shows a section of such a desert surface, a typical mobile sand surface,

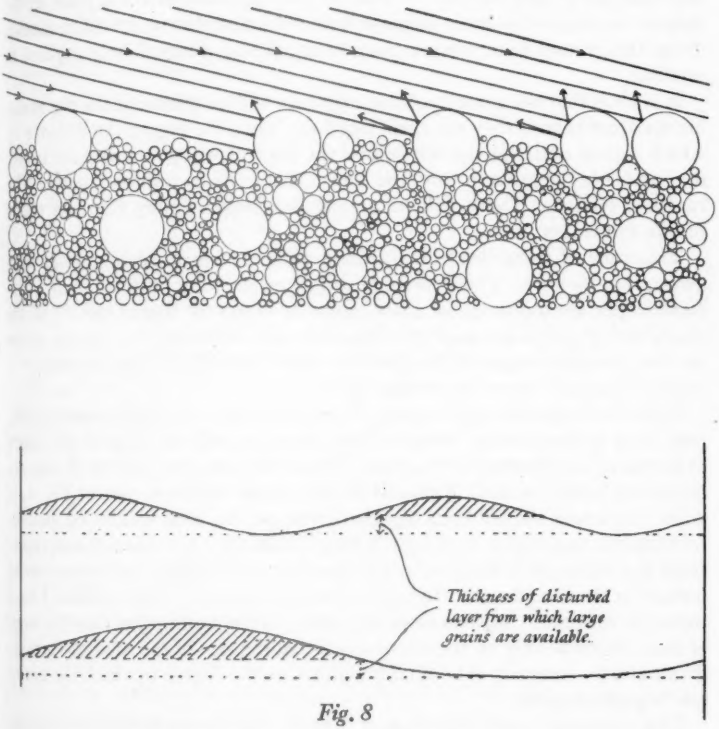


Fig. 8

[1] A giant ripple is a definite sand formation. It is a short isolated ridge lying transversely to the direction of the wind, its windward slope being very gentle and its leeward slope very steep. The crest sometimes rises above the surrounding sand or pebble surface, in which case the ripple is often classed (erroneously, as I think) as a very small dune. The crest is however sometimes at ground-level and is followed by a trench. The distance from crest to crest of successive ripples ranges from 20 cm. to about 6 metres. In scale therefore the giant ripple lies midway between a normal sand ripple and a true dune. In shape it resembles neither, and I have never seen any transition forms by which a normal little ripple may be supposed to grow into a giant ripple or the latter into a dune. Unlike a true dune, where the finest grains of sand are found at the top, the giant ripple consists of coarse grains whose coarseness increases towards the top.

magnified twelve times. Suppose also, for simplicity, that the wind strength is such that the biggest grains are just not picked up by it, and therefore do not form part of the sand-cloud.

The bombardment from the sand-cloud overhead will be on average as intense at one place as at another, so I have represented it as a series of parallel lines evenly spaced and inclined to the horizontal at the sort of angle we may expect, after looking at the table given on p. 351, to be an average angle of descent. The effect of the bombardment upon the big grains will be roughly proportional to the number of flying grains which strike them during any reasonably long period. So that we may suppose that if a grain in the diagram is exposed to three incident lines of bombardment, it will be hustled along the ground faster than a grain of equal size which is only exposed to one line.

It is clear that the amount of this exposure will be greater if the big grains are far apart than if they are close together. Thus the bigger the distance by which a grain outstrips the one behind the faster it will go on, and the nearer it approaches the grain in front the slower that grain in front will move. The result is obvious. There will be among the bigger grains alternate traffic blocks and empty spaces.

This state of instability will continue until the blocks of big grains have grown into mounds. These mounds will go on growing until (*a*) their windward slopes are too steep for more grains to climb up them; and (*b*) all the available big grains are used up. Since we have assumed that the big grains are not present in appreciable numbers in the sand-cloud, the only source of supply is local, *i.e.* from the surface layers.

If we take it that the layer of sand disturbed by the wind is limited in thickness, only a certain total volume of big grains is available from it per metre of length in the direction of the wind. Hence the size and number of mounds per metre is also limited. This will be clear from the lower part of Fig. 8, in which the upper shaded areas together represent the total volume of mound-forming grains available in the given length, and the lower shaded area represents the increased volume of grains necessary if a bigger ripple were to be formed in the same length. In each of the two curves of ripple outline I have made the maximum angle of slope the same, on the assumption that the angle of slope depends only on the relation between the size of the mound-forming grains and the intensity of bombardment, *i.e.* on the degree to which the grains can be pushed uphill.

This maximum angle will depend, I think, not primarily on the absolute size of the biggest grains but upon the ratio of this size to that of the average flying grains in the sand-cloud; for an increase in the size of the latter would entail a great increase in the momentum with which each of them can strike the big ones.

Conversely, since a grain which is half the size of another and is moving at the same speed will have only an eighth the momentum of that other, even a slight decrease in the average size of the grains in the sand-cloud may be sufficient to prevent them from imparting any movement to the bigger constituents lying on the ground.

Thus, supposing that we had a sand consisting of two main groups of grains

separated in the distribution curve by a wide range of size in which very few grains were present, we should expect little or no rippling to be possible because none of the grains of the small-sized group would be able to move the massive grains in the large-sized group.

In Fig. 7 we have three samples of normal unrippled desert floor, and in each case the gap is very evident. I have obtained rather striking confirmation of the truth of this idea from samples taken from a peculiar plain of sand on the plateau north of Dakhla Oasis where, although all the grains are small enough to be picked up by a normal wind, yet the surface is absolutely smooth, as if flattened with a trowel; and there is no sign of a ripple anywhere. A

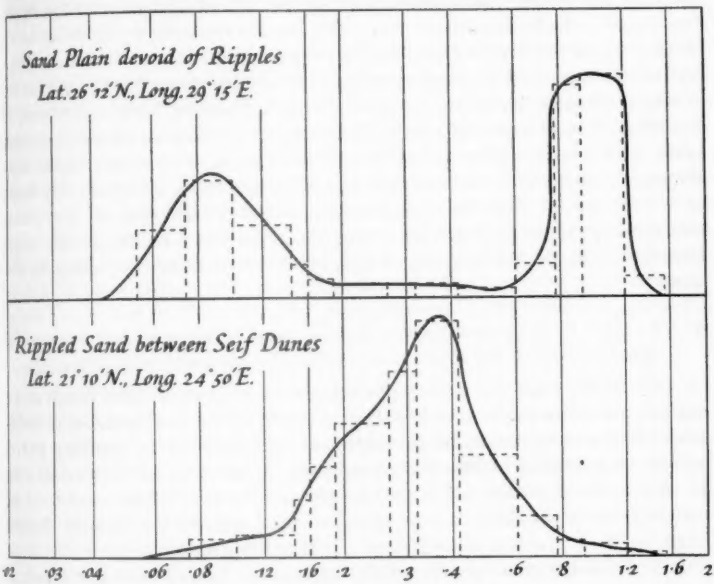

Sand Plain devoid of Ripples
Lat. 26°12′N., Long. 29°15′E.
Rippled Sand between Seif Dunes
Lat. 21°10′N., Long. 24°50′E.
·02 ·03 ·04 ·06 ·08 ·12 ·16 ·2 ·3 ·4 ·6 ·8 1·2 1·6 2
Diameter of Grains in millimetres

Fig. 9

glance at its distribution curve, the top curve in Fig. 9, will provide the explanation at once.

One difficulty in this particular case will however occur to the reader. How is it that if all the grains are small enough to be picked up by a normal wind only the smaller-sized group has been considered as providing the motive power of the ground movement? I think the answer is that whenever the wind is strong enough to pick up the big grains, it may be expected to begin by scattering any of them which happen to have begun to form incipient mounds and have so become more exposed.

If, on the other hand, we want a sand which will ripple easily in all winds, it is evident that its distribution curve should consist of a single, wide, flat hump, so that in a wind of any strength there will always be a good quantity

of grains lying about which are just too big to be picked up by the wind. The bottom curve in Fig. 9 shows a typical curve of a good rippling sand.

The origin of the giant-ripple presents more difficulty, since it is almost impossible to obtain a true sample from a formation which covers such a big area of ground. But I rather believe that the grain distribution which gives rise to it is similar to that in the top curve in Fig. 9 if this were to be shifted bodily to the right. The relative coarseness of the grains in the giant-ripple is well known.

I must apologize for adding one more to the many existing pictures painted to explain the rippling of wind-blown sand, but I claim that the foregoing is the only one so far which can explain (*a*) the initial formation of the ripple from a smoothed-out surface: this point has always been a stumbling-block in the way of any explanation based on wind eddies; (*b*) the limitation in the size of the ripple and the constancy of size in any given conditions; and (*c*) the marked influence, noted by Vaughan Cornish, Harding King and others, of the proportion of grains of various sizes present in the sand on the shape and scale of the ripples. The actual fact of the accumulation of the bigger constituents into the crest of the ripple is, I think, generally accepted. The basis of my picture is that the direct motive power which acts on the grains and arranges them into ripples is not the wind but a continued low-angle bombardment by flying grains which are themselves set in motion by the wind.

5. *The effect of the ground surface upon the sand-cloud: a possible cause of the apparent mutual attraction of sand grains for one another*

"One of the most interesting phenomena in connection with dunes is the curious power they appear to have for collecting all the sand in the neighbourhood. It is not an uncommon thing to see an isolated dune standing in the middle of a sandless plain with no ripples or dunes to be seen anywhere near it. When this is considered it seems very curious that all the sand from an enormous area should be swept up, as it were, into such a sharply defined heap."—W. J. Harding King (*Geogr. J.*, March 1916).

It is a certain consequence of the hypothesis I have here put forward, namely, that the sand-cloud moves along by a succession of bounces and hops on the part of the grains composing it, that each grain must on the average have its forward velocity checked or destroyed when it reaches the ground and strikes any object (other than a perfectly smooth, level surface, which case will be dealt with later). Every time it rises into the wind-stream again its forward velocity will be restored, *i.e.* it will have fresh forward momentum given it by the wind. Momentum must therefore be continually extracted from the air; which is another way of saying that the air suffers a continuous resistance while the sand-cloud is being maintained by it.

If a steady motion is to be maintained therefore additional momentum must be supplied to the wind from some external source. The most likely source is the faster-moving sand-free air above the cloud which may, by a slow convection, come in to take the place of the air below, whose velocity has been checked by the sand-resistance.

Supposing that under given atmospheric conditions the rate of supply of

this additional momentum is limited, then the rate of the removal of momentum by the sand grains must also be limited. In other words, under given atmospheric conditions the wind is only able to sustain a limited sand resistance. If this resistance is to be kept constant at this limit, it can be shown that the weight of sand flowing per second down an imaginary lane of a given width varies as the ratio of the average length of a hop to the final forward velocity with which the average grain strikes the ground at the end of the hop. This ratio, as was pointed out in Section 4, decreases rapidly if the average velocity of rebound of the grains is reduced. If therefore the conditions are such that the average velocity of rebound is reduced, the weight of sand flowing down wind per second must also be reduced, provided the surrounding atmospheric conditions remain the same.

Dr. J. S. Owens has lately drawn my attention to a short paper by him in *The Engineer* of March 1927 describing a low sand-cloud 4 inches high driven by a wind of 15·34 miles per hour (some 2 miles per hour faster than the wind speed necessary to start the grains in motion in the first instance). He gives numerical results of his measurement of the quantity of sand which was flowing past a given line per hour. From these figures I deduce that the ratio of sand flow to air flow, by weight, was 1 to 60, which shows that the weight of sand present in the air though small was quite appreciable. I have no other figures for higher winds, but it would seem that the resistance of a quantity of sand of this order would be quite sufficient to affect the flow of air. Incidentally, in the same paper Dr. Owens recorded the sand grains as appearing to move in a succession of hops, and to be lifted by impact with grains on the ground just as I have postulated in the present paper.

In the preceding section, when dealing with the state of affairs on the ground surface, we assumed the sand-cloud to be unaffected by the changes in the texture of the surface. This was because the ground grains were larger, and their individual masses consequently a great deal larger (the mass varying as the cube of the diameter) than the flying grains of the cloud, so that the former behaved as massive anvils off which the flying grains could bounce with almost undiminished velocity.

But now picture our sand-cloud to pass on until it reaches a patch of surface where the grains are the same size as some of the grains composing the cloud. These grains in the cloud will now no longer rebound as before when they strike the ground, but will sink in, causing a kind of splash which will throw up a number of grains a few centimetres into the air. Even though initially a number or grains may rise up for every one that hits the ground, yet with each one of them the average velocity of rise will be smaller, so that the number of times the grains are checked and re-started during their drift down wind will be increased. As we have just seen, this must lead to a reduction in the total weight of sand moving down wind per second, owing to the limited motive-power available.

The result is obvious. Since sand is arriving at a certain rate, and since the amount that flows on is now less than that arriving, some sand must leave the cloud. We thus reach the conclusion that whenever a sand-cloud comes to a patch of surface composed of grains of the same size as, or smaller than, those in the cloud, a proportion of the sand in the cloud must be deposited.

I think this effect provides a possible explanation of the fundamental phenomenon of dune formation, a statement of which by Harding King I have quoted at the beginning of this section. For if, whenever casual sand grains lying in its path are driven hither and thither by the wind, a proportion of them are deposited wherever sand accumulations happen to exist already, these accumulations must eventually grow at the expense of all the casual sand in the surrounding country.

As I see it, the action which takes place when a cloud of sand grains of mixed sizes reaches a patch of surface sand will be as follows: The flying grains whose size is equal to or larger than the bulk of the surface grains will drop in with a splash and will remain where they are until possibly they are picked up again by the lifting effect of the differences of pressure near the ground-level. Smaller grains will be driven on over the surface, bouncing off the bigger grains till (*a*) they lodge in cavities between them, or (*b*) they reach a patch of sand where the surface grains are about their own size or smaller. Here they too will accumulate. Such exclusive accumulations of fine grains should only be found in positions inaccessible to their big brothers owing to height or steepness of slope. This is borne out by observation, for fine grains by themselves are only found on the steep crests of dunes. If no such inaccessible places are available, the surplus fine grains will drift on down wind. The bulk of the sand will consist of an aggregate of grains of all sizes arranged so that cavities between large grains are occupied by smaller ones, down to tiny entrapped dust particles. (A great deal must of course depend on the composition of the grain supply from up wind. It may have ceased altogether.)

Fig. 10 shows two typical distribution curves for samples of the finest accumulated sand, found at the highest crests of "seif" dunes. The curves of other samples, taken from the tops of seif dunes many hundreds of kilometres apart, are very similar in shape. In no case does the peak of the curve lie below 0·15 mm. diameter, or above 0·3 mm.; 80 per cent. by weight of the grains are between 0·3 and 0·1 mm. in diameter. It would be most interesting to discover why there is this lower limit of size, and why, at any rate in the Libyan Desert, grains of smaller size do not accumulate together. That smaller grains exist in fair quantities is shown by the curves already given, but in all cases the smaller grains are merely entrapped by bigger ones.

Meanwhile a scattered army of little pebbles whose size prevents their being picked up by normal winds, may be creeping very slowly down wind along the ground, driven on by the bombardment of the sand-cloud. If the sand accumulation on the ground is small, and its slopes gentle, the pebbles will creep on over it. They will act as anvils and will increase the average height of rise of the driving sand grains when the latter strike them. They will thus speed up the sand flow, and so retard, if not prevent altogether, the growth of the accumulation. If however the accumulation can grow more rapidly than the pebbles can spread over it, or if its sides can become too steep for them to climb, a dune may start to grow. It will be a race between the two tendencies, towards growth on the one hand and removal on the other.

Reverting for a moment to the effects of the sand-cloud on the air around it, there is a further theoretical way in which the sand grains might act on the air. The horizontal resistance has already been noted. There should also be a

vertical pressure due to the fact that the grains will in general rise off the ground with a higher vertical velocity than that with which they fall again. This will cause a resultant upward pressure on the air. Over perfectly even ground, and assuming no convection currents, there would be a corresponding

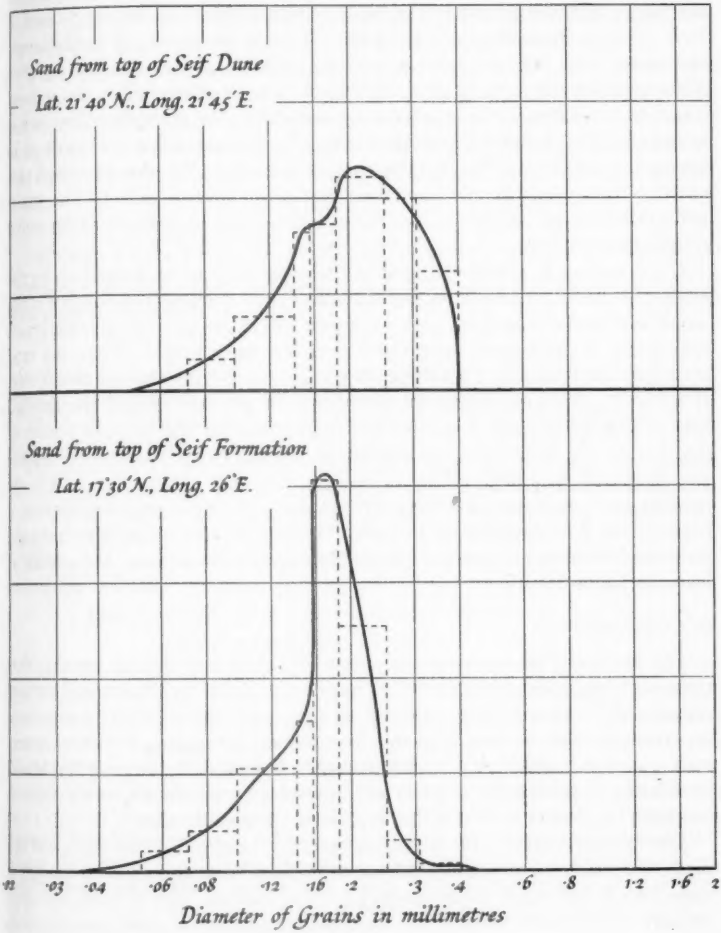

Sand from top of Seif Dune
Lat. 21°40′N., Long. 21°45′E.
Sand from top of Seif Formation
Lat. 17°30′N., Long. 26°E.
·02 ·03 ·04 ·06 ·08 ·12 ·16 ·2 ·3 ·4 ·6 ·8 1·2 1·6 2
Diameter of Grains in millimetres

Fig. 10

minute drop in barometric pressure near the ground which would give rise to a state of instability. Any local unevenness or change in ground texture would therefore cause convection currents to form in the wake of it, thereby relieving the pressure difference. Hence it is just possible that these two effects together might produce a peculiar sort of convection controlled by the form and texture

of the ground underneath and rooted, so to speak, to fixed places on the ground. Possibly this may in some way be involved in the very large scale repetition of dunes in extremely flat areas of desert.

Finally, let the sand-cloud pass over a dead-smooth surface composed of cemented particles so small that impact with them does not appreciably reduce the horizontal component of the velocity of the grains in the sand-cloud. I have in mind the surface of a mud-flat. Here, if the surface is hard enough, the grains may bounce, but the forward velocity of rebound will be little different from the forward velocity with which the grain strikes the surface. The grain will therefore not offer any resistance to the air-stream, and as it is not checked in its motion each time it touches the surface, it will move at an average speed little different from that of the wind. We should expect that such surfaces would be the least likely places for sand to collect. The grains will glide over the surface in the manner described by Jeffreys in his paper referred to on p. 349.

If the surface is a mud-flat, and is friable enough to be broken up by the impact of the flying grains, we should expect such damage to occur first at the windward border where the angle of impact will be steeper owing to the grains falling out of the normal sand-cloud from a greater height. Thus any sand accumulation found on a mud-flat should encroach from the windward side. If however an accumulation already exists on ground beyond the leeward side, it may grow until it encroaches backwards over the leeward border of the flat. If the meteorological conditions are such that the average annual rate of sand flow is fairly uniform through, say, 180° of direction (which, be it noted, is not at all the same thing as the absence of a prevailing wind direction, because the flow depends on the wind strength as well as its direction) the sand accumulations may encroach from all directions, leaving, for a while at least, an isolated hollow.

6. *Conclusion*

The foregoing are some consequences of a mere hypothesis, namely, that rebound from impact on pebbles or large sand grains on the ground surface supplies the upward force required to keep sand grains aloft. Laboratory experiments seem to show that this hypothetical bouncing motion of desert sand grains is possible and indeed probable, but since developing the idea I have had no opportunity to carry out any direct experiments in the field to ascertain the degree to which this mechanism preponderates.

The various results of the hypothesis seem to hang nicely together, and the suggested mechanism would continue to explain many things even though it were found that other mechanisms, *e.g.* wind eddies, were at work simultaneously. They most probably are, especially in the case of severe sandstorms.

Allowing for less perfect elasticity and a lower density on the part of the grains, I think that the same mechanism of bounce could be applied to other materials than sand. The collection of dry granular snow, for instance, into small dune-like forms may be brought about by the same agency.

If the explanations I have tried to sketch turn out in the end to be wrong they may, in the process of disproof, at least serve to stimulate experiments and observations on the underlying phenomena of sand movement, so that

later we shall have something to build on when the probably far more complex questions of dune morphology come to be tackled seriously.

There are too many gaps in our knowledge of the facts for much building to be done at the present time. I think that the worst of these gaps are (1) the lack of long-period data on the combined strength and direction of the winds in sand-dune areas; and (2) the lack of correlation between the rate of the mass-movement of sands and the strength of the winds that drive them.

When more knowledge is obtained it may be possible later on to use the enormous, geometrically regular, and slow-moving structures of the dunes as keys to the past climatic history of the countries in which they lie, in something like the same way as that in which the annual deposition of glacial debris has enabled a time scale to be worked out for the recent climatic history of Europe.

APPENDIX I: THE WIND-RESISTANCE OF SAND GRAINS

The resisting force R offered by an object to a stream of fluid flowing past it with a relative velocity v is given by

$$R = c \times {}^1\!/_2 \rho a v^2$$

where ρ is the density of the air. (I have taken this as $1{\cdot}22 \times 10^{-3}$ for air of medium humidity at 15° C. (see Prandtl, 'The Physics of Solids and Fluids,' p. 175).) a is the cross-sectional area of the front of the object exposed to the flow, and c is the resistance coefficient.

Unfortunately c is not constant except under special conditions, nor, except for very small particles (smaller than those with which we have to deal), is it given by any mathematical expression. Practical values of it have had to be found by experiment.

The special conditions under which objects of similar shapes have the same resistance coefficient is expressed by

$$\frac{\text{Linear dimensions of object} \times \text{Relative velocity}}{\text{Kinematic viscosity of fluid}} = \text{Constant.}$$

The value of this expression is known as the Reynolds Number. As long as the Reynolds Number is constant, c remains the same, even though the factors within the Reynolds Number vary between themselves. It is therefore usual to give the experimental values of c for variously shaped bodies in terms of the Reynolds Number. The kinematic viscosity varies with the fluid, its temperature and pressure. Throughout this paper I have taken it as 0·146 cm.²/sec. for air at 15° C. and 760 mm. pressure. At 40° C. and the same pressure it is 0·167 (see Ower, 'The Measurement of Air Flow,' p. 108). In the case of a sphere the linear dimension is taken as the radius. The Reynolds Number of an ideal sphere is therefore taken as $vr/0{\cdot}146$, and to find the theoretical air-resistance it is merely necessary to look up the experimental value of c corresponding to this particular Reynolds Number.

The range of magnitudes with which we are concerned are as follows:

Sand grains of radii $r = 0{\cdot}001$ to 0·1 cm.

Relative velocity of grain and wind

$$v = 10 \text{ to } 2 \times 10^3 \text{ cms./sec.}$$

Reynolds Numbers between 10^{-2} and 10^3.

Between these limits of Reynolds Number the resistance coefficient increases rapidly, for a given grain size, as the Reynolds Number decreases. For values

of the Number below 10^{-2} the resistance follows Stokes' Law, c is calculable and varies inversely as the Reynolds Number. For values between 10^3 and 10^5, c remains nearly constant. Sand phenomena therefore occupy a particularly complicated region of the velocity-resistance relation, an incalculable region between Stokes' Law on the one hand and a constant value on the other.

A further complication must also be noted. It has been found that a smooth body has, by virtue of its smoothness, a different value of c, for a given Reynolds Number, to that of a sharp-cornered body of the same dimensions. There are thus two sets of experimental curves connecting the Reynolds Number with the resistance coefficient c, and we have to determine whether a sand grain should be classed as smooth or sharp.

In dealing with the motion of a grain through the air, the most useful quantity associated with it is not the absolute wind force upon it, but the ratio of the wind force to the force of gravity, *i.e.* R/mg. I have calculated the values of this ratio, which I will call the Susceptibility of the grain (denoted by S), for ideal spherical grains of quartz (density 2·65) of various sizes, in a wind varying from 10 cm./sec. to 4000 cms./sec., for smooth bodies, using the values of c given on p. 316 of Prandtl's paper (*op. cit.*). These values are given graphically in my Fig. 2. From this the linear acceleration of a quartz sphere, in terms of the instantaneous relative velocity, can readily be found by multiplying the appropriate value of S by g.

The acceleration of a sphere falling through still air is given by $g(1-S)$ and that of a sphere shot vertically upwards into still air, by $-g(1+S)$. By dividing the range of velocity into a number of small elements, and treating the acceleration as constant for each element and equal to that corresponding to the mid-velocity of the element, the vertical motions of a spherical grain through still air can be calculated with fair accuracy and quickness. Remembering that the air-resistance always acts in a direction opposite to the instantaneous motion of the grain through the air, and assuming as an additional approximation that during an oblique curved flight the direction of motion for a small element of velocity change is that midway between the initial and final direction, it is possible by a geometrical construction to find the approximate trajectories of grains fired into the air at any angle of inclination.

APPENDIX II: NOTE ON THE CONSTRUCTION OF SIZE-DISTRIBUTION CURVES OF SAND SAMPLES

The object of the curve is to represent the make-up of any sample so that the percentage by weight of grains whose sizes occupy any particular element of the whole scale of size can be seen at a glance. The sand is put through successive sieves and each fraction is weighed. The sieve-apertures are also measured microscopically. Since the measured aperture size of a sieve usually bears no fixed ratio to that of the one next below it, the elements of the size scale represented by two successive sieves is purely arbitrary, some elements being very big and some very small. Hence a diagram in which the heights of a given portion of the curve represented the actual weights of sand passing one sieve and not passing the next would convey no useful information because the weight of sand isolated by the pair of sieves, the ratio of whose apertures was big, would itself be correspondingly big, and a misleading peak would be shown on the curve.

If however the weight of each of the fractions is divided by the ratio of the sizes of the two sieves isolating it, and the result is shown as a height in the diagram, the height of any portion of the resulting curve will show the weight

per unit element of the size scale. The area bounded by the curve and the vertical lines corresponding to the actual size limits of the element will then show the proportionate weight which that fraction bears to the whole weight of the sample as represented by the whole area under the curve.

In order to compare the curves of different samples it is necessary to reduce all the weights so that the total area of each curve is the same, and represents, say, 100 grams of sand. All the fractional weights are therefore divided by the total weight of the sample before plotting.

As regards the size scale along the bottom of the curve: an ordinary linear scale is awkward because undue prominence is given to big grains and the smaller sizes are squashed up into the left-hand corner. We are not concerned with the intrinsic size of a grain so much as with the ratio of different sizes. A scale should be used therefore in which equal ratios between sizes occupy equal lengths on the scale. I have accordingly plotted all my distribution curves on logarithm or ratio paper. It will be seen that in the curves the step from, say, 0·02 to 0·04 is the same length as the step from 0·08 to 0·16 or from 0·3 to 0·6, and the step from 0·02 to 0·2 is the same length as that from 0·2 to 2.

The only difference this makes in the construction of the curves is that the fractional weights, after being divided by the total weight of the sample in order to give the whole curve a standard size for comparison with other curves, must be divided again, not as at first by the ratio of the aperture sizes, but by the logarithm of that ratio, in order to give heights which will make the enclosed elementary areas represent the elementary weights.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: Major Bagnold is going this afternoon to read a paper on "The Movement of Desert Sand." Major Bagnold is known to many of you and is not new to this platform. For years he has been making a special study of sand in the Libyan Desert. When he was in India he used his leave for the purpose of going to explore in the Libyan Desert. The particular direction in which his activities led him was in seeing how far the desert could be explored by motor car. He has performed some wonderful feats in getting cars over desert tracks. The movement of sand is an interesting and very complicated question. Major Bagnold has some important theories to put before us and I hope we shall afterwards have an interesting discussion.

Major Bagnold then read the paper printed above, and a discussion followed.

Dr. K. S. SANDFORD: I think we must distinguish, more carefully than we have in the past, movement of sand over a featureless plateau from its reactions to broken ground and scarp country. In the former Major Bagnold has shown that turbulence does not sufficiently explain the picking up or transportation of grains. Dr. Jeffreys has calculated that pressure-differences will raise the grains, and Major Bagnold's ballistics, bounce, splash, and shove-halfpenny-like advance of an army of small pebbles seem to account for the rest. But he still invokes turbulence to account for the high dust-clouds—and is undoubtedly correct in so doing—though he distinguishes a downward drift of air to take the place of that retarded by the resistance of the flying grains. We must therefore allow for some vertical interchange of air yet to be fully explained, but I suggest that the author has gone far towards the explanation of that blizzard-like rush of sand without gusts, plumes, or air-pockets free of sand. These features do not suggest turbulence, nor do the resulting forms of dunes and ripples. The arresting of sand by soft ground is an important point. In broken country, on

the other hand, we see an abundance of eddies, wind-shadow dunes, scoured pockets, and local submergence of topography by sand, and in a high wind we can see plumes of sand: the conditions are quite dissimilar from those described by the author, and for the most part have been adequately explained in the past. "Sand-storm" is an inexact word to describe the unvarying rush of sand over and along the surface: in many of its characters of movement and deposition it so closely resembles the blizzards of a smooth ice-cap that "sand-blizzard" might be a permissible term.

Major Bagnold is to be congratulated on his pioneer work in the desert and in the laboratory, and it is greatly to be hoped that he will continue these profitable researches in both places.

Dr. VAUGHAN CORNISH: Major Bagnold's ingenuity and industry in the conduct of experiments suggested by his observations in the field deserve our highest admiration. It is clear that the bouncing of the sand-grains, the amount of which Major Bagnold has measured, is largely responsible for the ripples which are sometimes produced when no dunes are formed and which always pattern the surface of sand-dunes. This is a definite and important step in advance which I am sure that further observations in the field will not invalidate. Suspension due to bouncing now appears to be the decisive factor in ripple-making, and the low cloud of bouncing sand-grains may also I think be the principal factor in the march of the detached crescent dunes on the hard floor of the Peruvian desert when travelling before the moderate breeze there prevalent.[1] But I think that whirling or eddying suspension is a large factor in the formation and growth of sand-dunes and snow-dunes, particularly in the case of a sequence of transverse ridges in deep sand-seas such as the Taklamakan desert. The descriptions, illustrations, and measurements in Dr. Sven Hedin's four quarto volumes of 'Scientific Results'[2] provide strong indications that transport in eddying suspension during storms is a large factor in determining the features of that desert. No one has been able to watch the operation there during great storms, when it is not possible to see and scarcely possible to breathe; but it seems likely that the process resembles that which I have watched when the light, fresh-fallen snow of the Canadian prairie flies in a strong breeze at a temperature so low that the flakes do not adhere. The vast train of travelling snow-dunes then formed is entirely unrippled on the surface whereas dunes of similar size in fine sand such as is observed near Helwan are rippled all over. The snowflakes are so fragile that they do not bounce on collision but disintegrate. Yet this does not hinder the formation of the snow-dune, the larger order of wave. The ripples or smaller order of waves were only seen where a granular material composed of hard particles of ice occurred. This material apparently originated in the melting of snow, its subsequent re-freezing and final disintegration.

So much for the mechanics. Now for the terminology. Major Bagnold is of opinion that the structures called sand-waves may perhaps be better described as repetition phenomena. From the literary standpoint the objection to the term "wave" which I introduced nearly forty years ago cannot I think be sustained; for one of the principal uses of the word "wave" from the sixteenth century to the present day, as is stated in the 'New English Dictionary,' is "an undulating conformation [and] each undulation of such a conformation." The examples given in the 'New English Dictionary' in this connotation apply moreover to materials which have no power of transmitting energy. The only ground there-

[1] See *Appalachia*, vol. xii, No. 1, and *Annals of the Astronomical Observatory of Harvard College*, vol. xxii, part ii.

[2] 'Scientific Results of a Journey in Central Asia 1899–1902.'

fore upon which it would seem that my application of the word "wave" can be disputed is the question whether it suggests the right or wrong track of thought. I have myself found it fruitful in suggestion and helpful in the coordination of phenomena which when studied together throw light upon one another.

I think the reason why a good many people have regarded the word as unsuitable is that almost every student of physical science in our time derives his notion of the essential character of waves from the phenomena of light, sound, and electricity, which are part of the educational curriculum, not from the superficial inequalities of rough water which, as the 'New English Dictionary' clearly shows, are the prototype of all waves. Waves are not identical in any two materials, and certain characters of water-waves are exhibited in the transmission of light and sound, others in sub-aerial and sub-aqueous sand-dunes. The late Lord Rayleigh, who achieved so much in the application of wave-theory to light and sound, once remarked to me that he considered that my extension of the term "wave" to the phenomena of drifting sand and snow was to say the least as well justified as the earlier extension of the term to light and sound.[1] I am glad to see that my extension of the term "wave" is now winning acceptance among mathematicians, some of whom, notably Dr. Harold Jeffreys, regard "waves in granular material" as a suitable subject for theoretical treatment.

I admire enormously the work of Major Bagnold and I am sure when he returns to the desert he will find out a great deal more; but I am quite certain that his mechanics of the bounce will last and that they are a definite contribution. I congratulate him on the vividness with which he has described these collisions because when I read his paper an enormous number of episodes of the football field recurred to my mind from the days long ago when one was still a hard body capable of moving at a high speed.

The PRESIDENT: I call upon Dr. Spencer, Keeper of Minerals at the British Museum, who has lately returned from the Libyan Desert.

Dr. L. J. SPENCER: I have been very interested in Major Bagnold's paper, but at the same time rather disappointed. I thought we were going to hear something of the geography of the Libyan Desert and how the marvellous dunes were made. Instead, we have been treated to a learned dissertation on pure physics. I expect when Major Bagnold goes again to the Libyan Desert he will have so many new ideas and so much to work on that he will be able to solve some of the problems. The dunes of the Sand Sea are certainly most extraordinary: they rise 300 feet high and run for 200 or 300 miles in parallel north-south ranges over a perfectly level plateau about 150 miles wide. The point Major Bagnold made as to the difference in size of the sand-grains was very striking. Some of the western slopes of the big dunes are speckled over with little red grains of carnelian and jasper, as if one had been sowing mustard seed. One does not see those on the eastern side of a big dune, only on the windward side.

[1] The circumstances attending the late Lord Rayleigh's comment were as follows: After returning from Canada in 1901 I showed enlargements of my photographs of snow-waves and sand-waves at the soirée of the Royal Society. Lord Rayleigh examined them and talked on the subject. I asked if he considered that my extension of the word "wave" to these phenomena was justified, and I was surprised when he went beyond that and said that it was "at the least" as well justified as the application of the word "wave" to the pulsations of light and sound. . . . But it was not until Lord Rayleigh spoke on the matter that I realized how much the old physicists had modified the original application of the word. . . . One of my points is that the customary limitations proposed for the use of this word "wave" by physicists are not in the interests of natural science as a whole. Lord Rayleigh was right: the word may be used in a special sense in relation to light, sound, and electricity, but it should not be withdrawn from geophysics in its application to surface phenomena.

During the recent expedition of the Egyptian Survey, which I was privileged to accompany, two interesting observations on the movement of sand were made. The surface of these dunes are wetted with dew and when you lie down on them in the early morning and look closely you will see the sand all dancing about in a most extraordinary manner, like little bombardments: the whole surface looks alive. I do not know whether Major Bagnold has observed that. It was first noticed by one of the Arabs with us. Another curious movement was when the stream of sand was running over a rock face. The rock was grooved out in the direction of the wind but a circular hole was drilled on the leeward side from the back of the rock, a perfectly cylindrical hole, an inch or less in diameter, penetrating from back to front. I do not know what happens to cause that.

The paper certainly needs to be studied carefully in print. We have scarcely had time to digest all that was read to us this afternoon, but I have been most interested.

The PRESIDENT: Sir Albert Kitson has been in West Africa, and over the desert by airplane along the Nile Valley and the Anglo-Egyptian Sudan.

Sir ALBERT E. KITSON: I do not intend to say anything regarding the mechanical side of the paper. I congratulate Major Bagnold on the manner in which he has made his arduous observations and has presented his paper. I should however like to mention one or two points that occurred to me when reading the paper. The author stated that 1 ½ metres was about the greatest height at which the coarser sand was carried along. Has he noticed any gradation to finer sand above that height, or is there simply a sharp break there? In the observations with regard to the movement of particles of sand in the air, was Major Bagnold able to make them in such a manner that his place of close observation did not affect the even flow of the air? For instance, when roughly gauging the volume of a stream it is necessary to stand well away from depth-measured sections when getting the average speed of flow so as to prevent obstruction to the water while thin paper floats are carefully released on the water by a stick.

As regards the sand-dune in the middle of a wide flat with no sand on the surface around, it seems to me unlikely that a dune would have been formed there by wind-borne sand from a considerable distance away. I should feel inclined to regard a geological examination of the dune as necessary to see if it were the remnant of a former bed of sandstone or sand on which wind had begun to operate owing to some opening for attack having been provided, and thus a dune of local sand formed. Definite evidence might thus be obtained to explain the formation. On the screen we saw dunes of different kinds which to me suggested the action of winds from different directions, not consistently from one direction only. Does Major Bagnold regard that as possible? It would be interesting to have results of observations in hilly areas with varying directions of winds and to compare them with the results from winds consistently, or nearly so, from one direction over fairly level country.

Major BAGNOLD: The first question raised by Sir Albert Kitson concerned the type of sand-cloud. As far as I can see the largest sand-grain will fly highest. The bigger the grain the higher it is possible for that grain to fly by pure bounce and, of course, the bigger the grain the less likely that grain is to be controlled by the turbulence of the air. But superimposed upon that sand motion one would have a background of fine films of dust which are supported by such turbulence as exists. For instance, in Mongolia there is a much greater proportion of dust than sand and the cloud is seen to be about 100 feet high. Most of it is supported by turbulence, but on the ground one gets the same effect as with a low-flying cloud of pure sand. One must distinguish between sand and dust. In the

Libyan Desert where there is practically no dust at all one sees a flying cloud of sand perhaps shoulder-high, so that people are walking about with their heads and shoulders sticking up as if they were in a swimming bath. Above them the air is almost clear. There is but a very faint suggestion of dust in the air, and one can see blue sky. In a severe sand-storm turbulence plays a much greater part: the whole cloud rises higher and nothing is visible.

As regards the question of the observer getting in the way and disturbing the air stream, that is a point which must always be guarded against. I have never yet really succeeded in observing the actual movement of the grains in the air. The relation between the size of the grains and the speed at which they move makes direct observations very difficult. I think there is little doubt that the dunes and dune systems of the Libyan Desert are built up of sand which has travelled a good distance—say up to 100 miles. In most cases there is a crumbling escarpment up-wind to account for the source of supply. When the bulk of the sand-grains were initially ground down from quartz rock is another matter.

The PRESIDENT: There is one question I should like to ask Major Bagnold and that is whether what we know as "singing sand" is covered by the work of Nature that he has been dealing with this afternoon or whether it is something due to the intrusion of man?

Major BAGNOLD: Personally I have never heard singing sands occur spontaneously, but I have met several people who have heard the singing. I have often made sand in dunes sing by walking over it or by squeezing it up in my arms. It always happens with fairly large grains very much rounded and absolutely clean, and with no small ones among them and no dust between them. Why it happens no one seems yet to have explained. The sound seems to be connected with the bulk of the sand which is moved. If a whole dune-cliff falls down the sand will give out a low note; or if one gathers up a large quantity of sand between one's arms one will get a low note. But if one takes a small quantity and claps one's hands together one will get a higher note with the same sand. Why that happens I cannot say.

The PRESIDENT: Mr. Beadnell, of the Geological Survey of Egypt, who has taken a great interest in Major Bagnold's work, was unable to come this evening owing to illness. He has asked that his congratulations be passed to Major Bagnold in view of the excellent work he has done, especially in the framing of the paper. I think we who may not be scientists must have appreciated the great worth which those who have spoken attribute to Major Bagnold's work and the paper he has given this afternoon.

I now ask you to join me in thanking Major Bagnold very much indeed, in congratulating him on his study of this question, and hoping that he will pursue it and that it will stimulate others to study, with the same interest, the question of the movement of sand.

HOUSE BUILDING IN THE HADHRAMAUT

W. H. INGRAMS

DURING a recent tour in the Hadhramaut my wife and I collected some notes on the building of houses. Each town in the country has its own individual characteristics. Although the houses of coastal towns are all of the familiar Arab type, built of stone rubble and whitewashed, there is a wide difference in the aspect of the towns themselves. Makalla, for example, is a miniature edition of Zanzibar—tall houses and narrow streets, sometimes not 6 feet across, while Shihr is a town of lower houses, wide streets, and open spaces.

In the Wadi Do'an the tall mud-built houses climb up the banks of the wadi. They are close packed, but it is in their interiors that they merit attention. The colour scheme is black and white and rusty red. Although there is practically no whitewash on the outside of Do'an houses the interiors of the better-class dwellings are spotlessly white. The ceilings of the rooms, which are lofty, are supported by carved pillars of *'elb* [1] wood, and all interior woodwork is of this material. The doors are set in wide heavily carved frames and the whole ornamented extensively with iron nails, 2 inches across the heads, burnished with lead, which shine like polished dollars. It is a modern development of Do'an houses that every room in the house should be provided with its own ablution room, and as a consequence they are really self-contained flats. The entrance door gives on to a passage into the flat, and there is usually not a door into the main living room but a Moorish arch either in the whitewashed wall or of stained *'elb* wood again studded with burnished nails. The ceiling is held up on rafters of *'elb* wood supported by the pillars previously referred to, the mud floor of the next storey above being laid over slats of date wood very attractively arranged in herring-bone pattern.

In Terim the principal feature is the large number of enormous dwelling-houses in a style copied from Malaya but built of mud bricks. The exterior of these houses is decorated with blue, green, yellow, and pink, which is not at all unattractive. Interiors are fitted with every up-to-date contrivance, electric light and fans, telephones, ice plants, and modern European conveniences in the bathrooms. Whereas in Do'an and Shibam there is scarcely a chair to be found these houses are replete with European furniture, albeit some of a rather florid style. Living in such houses as these one is struck at every moment with the reflection that there is hardly a thing in the house that has not had to be transported on camel back over the mountains for six days, and while I mention this it is worth recording that there are sixty cars in Terim itself, each of which has been transported in parts by twelve camels from the coast.

The principal structural detail that the wealthy Seyyids of Terim and Seyyun have to contend with in their building operations is the difficulty of getting long enough timber. The *'elb* or *sidr* tree trows to no great height, and although we found *'ariata* trees growing to 50 feet or more in height some days' journey down the Wadi Maseilah, they cannot be transported by

[1] The commoner Arabic name is *sidr*, *Rhamnus nabeca*.

Foundations of a house in Do'an, showing blood of the sacrifice

Later stage in house-building, Do'an

Looking from the roof of a seven-storey house in Shibam

camels. The difficulty is being got over to some extent by experiments in making reinforced-concrete pillars, of which we saw two in construction at Seyyun. All the work is done by local labour, the travelled Seyyids training their masons. The interior walls of these houses, apart from elaborate decorations such as gold crowns and coloured flowers, consist of a lime plaster polished by smooth pieces of flint till it resembles marble.

Shibam is remarkable for the height of its houses. The town, which is in the shape of a capital D, contains in a small area five hundred houses built on a slight eminence in the wadi. From a short distance the whole town appears to be one enormous brown mud-built construction with a whitewashed top storey and roof. There is no further building room in the town, and the only way to have a new house is to buy an old one, knock it down, and rebuild. The area of land required to build a house 45 *dhirras* in width by 35 in depth (a *dhirra*, or cubit, equals 1·5 foot) will cost 10,000 dollars, and having acquired the land the prospective builder will have to submit the specifications of his house for the approval of a committee of the townspeople who consider the position of windows and of gutters carrying water to the street. Subsequent alterations to a house must also be similarly approved. By general consent houses in Shibam are not now to be built more than six storeys high, in order to avoid overlooking. The only important existing exception to this rule is the Government palace, which is a storey or two higher but which is in such a position that it overlooks very little. On the top of the six storeys the builder may however erect a roofless seventh which gives him a walled-in roof terrace. The building of this house, which, when completed, will be 64 *dhirras* or 96 feet high, will cost more than 20,000 dollars.

The foundations are dug 2 *dhirras* deep below the surface of the earth and 3 *dhirras* wide. Stones are used for the foundation mortared together with a mixture of wood ash and lime. In places where there is any doubt as to the solidity of the ground on which the house is to stand long pieces of *'elb* wood are laid in pairs lengthwise in the foundations. Wood for this purpose must be cut in the winter; if this is done it is said never to rot. The stone foundation or *sās* is continued for 2 *dhirras* above the level of the ground. When the building operations have reached this stage a foundation sacrifice of a goat or sheep is made on the walls. The house is centred round a solid pillar built on the same foundation as the walls. For a house of the dimensions proposed this pillar or *'arus el beit* will be $3\frac{1}{2}$ by 3 *dhirras* wide and of the same thickness from top to bottom. The stairs of the house invariably go up round the *'arus*. The bricks are made of clay mixed with straw, the standard size being $1\frac{1}{4}$ *dhirras* in length by $\frac{2}{3}$ in breadth by 4 *banan* or fingers' widths in thickness. When the clay of the required consistency and thickness for making the bricks has been laid out they are cut out by a wooden frame which makes two bricks at a time. The bricks cost five dollars a thousand.

The thickness of the walls of the first storey is $1\frac{7}{8}$ *dhirras*, of the second $1\frac{1}{2}$, of the third $1\frac{1}{4}$, of the fourth 1 *dhirra*, of the fifth $\frac{3}{4}$, of the sixth $\frac{5}{8}$, and of the seventh $\frac{1}{2}$ a *dhirra*. The bricks are mortared together with wet clay. As *'elb* wood grows to no great length the size of the room is determined to some extent by the length of the pieces available as girders. The girders are usually very short and supported by carved pillars each costing about twenty dollars.

Looking from the roof of a seven-storey house in Shibam

The ground floor of the house is usually the highest and the others are all about the same. Some of the houses in Shibam are built on the slope of the hill and are therefore provided with cellars. The height of the wall facing the outside of the city in these circumstances is about 70 *dhirras* or 105 feet high. Bigger houses are constructed of two or more houses built together.

The life of a house is said to be two hundred to two hundred and fifty years, but the age it reaches depends on the privies being kept dry and cleaned out regularly. If this is not done the damp saps the lower part of the clay walls and causes splits necessitating demolition. Outside the walls of Shibam in the rich man's suburb of Seheil there are villas, some of them built in East Indian style but none of them as big as those in the city. Several houses in these Hadhramaut towns are provided with most attractive and welcome swimming pools in which the water is usually kept running by means of small petrol engines.

The general principles of house construction seem to be pretty much the same all over the upper Hadhramaut, but it is really only in the main wadi that elaborate structures are found. Apart from the *dars* in which many of the tribesmen live, it may be interesting to record that in one wadi through which we travelled to the north of the main wadi towards the desert we found troglodyte Badawin living in caves in the walls of the wadi. The front of these caves was usually built up with dry stone walling, leaving only a small gap for the entrance of man and beast. Down the Wadi Maseilah between Qabr Hud and the sea the Manahil and the Mahra live in huts built of sticks not more than 5 feet high. In two villages on the Mahra coast many of the inhabitants lived in tents.

SCREE WITH GREAT BOULDERS

THOMAS HAY

A FEATURE connected with modern scree formation and the occurrence of great boulders must often have struck observers in the Lake District. Below the modern scree of comparatively small material, and sometimes separated from it by a gap, sometimes not, there is a slope, sometimes at a lesser angle, occupied by much larger boulders. For a long time I have felt convinced that in some cases these larger boulders were not the result of sub-aerial denudation but were a definite glacial feature. It has however been impossible to prove this conviction, and consequently it was a source of considerable pleasure during a stay at Pordoi in the Dolomites to come across indubitable proof of this conclusion. It may be said in the first place that the boulders in question are completely angular and are not in the least rounded or worn or scratched like erratics which have travelled some distance in the ice. They may be mixed up in nearly all cases with some other boulders which have descended through sub-aerial agencies or which have slid down a snow or ice slope. But this short note is intended to show that in many cases they

1. *Looking west through the Pordoi Pass along the Arabba-Pordoi road to Sasso Lungo: scree and boulders visible at foot of Sasso Beccie*

2. *Looking across the end part of the tongue: in the middle of the picture is the hollow marked "c" on Plate 1*

3. Among the big boulders, looking down over the tongue to Arabba far below

4. Great boulders near Auterstone on the west slope of Swarth Fell, Ullswater

are definitely the result of small hanging glaciers even when no other evidence of the presence of such glaciers may exist.

At the north-east foot of Sasso Beccie, the mountain which dominates Pordoi Pass on the south, lies a collection of great boulders. Higher up the hillside and lying at an angle of about 30° or more there is the modern scree of much smaller material. The shape of the place occupied by the great boulders is roughly that of a tongue stretching out from the Sasso towards a point rather south of Arabba, and it lies on the right-hand side of the Pordoi–Arabba road. The lower part of the tongue was generally speaking flat except for the great irregularities of the huge boulders and in the middle of it there was a distinct hollow. On Plate 1 the tongue is marked *a* and the steeper scree slope *b*, while *c* marks a hollow which might well have held a small tarn had the material been other than limestone, *d* the 50-foot drop to the road, *e* a dry water-channel, *f* the relic of a lateral moraine, and *g* an older position of the same. The last two features, which are not actually visible on the photograph, also occur in corresponding positions on the other side of the tongue.

The striking thing was the great collection of boulders merging upward into the modern scree, and the glacial features were entirely unnoticeable until a very careful survey of the whole formation was made. Most of the big boulders were in the part which was recognizable as definitely glacial. Yet to a more or less casual inspection the whole formed a mere collection of big boulders which might be assumed to be sub-aerial work. On the other side of the Pordoi Pass and on the road leading down to Canazei there is a similar and larger wilderness of great boulders without (as far as I am aware) any definite evidence of glacial action in the shape of moraines. After seeing the Sasso Beccie group no one would hesitate to class the second lot as almost wholly the deposit of lingering hanging glaciers on the slopes of the Sella group.

Exactly similar to, though on a smaller scale than, this second group of great boulders, are some that we find on the fell slopes in Lakeland. There is a remarkable group in the combe above Hard Tarn on the east slope of the Helvellyn range. Another occurs on the slopes of Swarth Fell, near Auterstone, and is shown in Plate 4. These are probably the result of a hanging glacier, possibly quite a small collection of fell ice. Great taluses of sub-aerial origin exist in this district, but there are others, which might at first sight be classed with them, which are almost certainly due to glacial action.

ARCHAEOLOGICAL DISCOVERIES IN UGANDA

G. CATON-THOMPSON

IN the *Uganda Journal*, vol. ii, no. 1, pp. 21–32, Mr. E. J. Wayland, Director of the Geological Survey of Uganda, publishes brief but arresting notes on certain ancient constructions of unknown age and origin in Uganda territory, and boldly calls attention to possible ancestral connections with Zimbabwe and the Rhodesian ruins. These constructions are described as earthworks, probable irrigation dams, stone cairns, pit dwellings, shafts, and middens.

The impressive earthwork, known to natives as Biggo bya Mugenyi (The Stranger's Forts), was noted over a quarter of a century ago, and described as a fortification consisting of an outer rampart and ditch over $2\frac{3}{4}$ miles long, with flanks resting on the Katonga River. Within the confines of this outer girdle a low central hill and earth mounds some 10 feet high were protected in similar fashion. The vallum though severely denuded stood 3 to 6 feet high, whilst the ditch, on an average 4 feet deep, attained in places a depth of 10 to 12 feet. To the west and east, some 4 and 6 miles away, are smaller hill-works, apparently belonging to the same system. In 1921 Mr. Wayland instituted closer observations, and sent Field Geologist A. D. Combe to report and survey. His plans are now published for the first time, together with extracts from his notes.

The plan of Biggo shows curved, univallate entrenchments, with the bank on the inner side; the central kraal, overlooking a bend of the Katonga, is encircled and bisected by its own fosse and vallum, and is further complicated by a pair of eccentric semi-circular loops of entrenchments which bud off from the main circle. The resemblance to many Rhodesian ruin plans is rightly noted. The widespread sweep of the outer earthwork, based on the river and doubled round adjacent higher ground, protects the site on the land side. A remarkable feature of the Biggo earthworks, repeated also at the outlying hill-forts, is the frequent break in the ditches, noted in plan as "communication outlets." No fewer than ten interrupt the outer line of ditch. The omission of details in an intentionally brief report leaves unanswered the archaeological query as to whether these causeways cut the vallum, a point which might throw light on their purpose, and justify the guess of cattle-raiding defences. In any case parallels with British Neolithic causewayed camps with their interrupted ditches spring to mind, though of course without the slightest implication of any connection in age and origin, though possibly of function.

The irrigation works at Ntusi, described and planned by Mr. Wayland, lie about $7\frac{1}{2}$ miles south-west from Biggo. They consist of two parallel earth dams about 50 feet wide by 20 feet high, with numerous smaller bunds lower down the valley and in converging ones. The semi-elliptical and inexplicable curvature of these dams recalls the Biggo and Rhodesian aversion to straight lines. Ntusi Hill itself is covered with animal bones and pottery outwashed from ancient middens. Unopened tumulus-like mounds, 15 to 20 feet high, lie in the vicinity; testing proved them to be middens, not graves.

Brief accounts of stone cairns, shafts, and pits complete the discoveries, which at certain points link up with comparable relics of unknown history in Kenya and Northern Tanganyika, for which the name "Azanian civilization" has elsewhere been proposed. With commendable restraint excavation was confined to tests in certain middens. Pottery, unlike modern native wares in form and fabric, was collected and is subject to report by the British Museum.

A short résumé is given of native tradition concerning these sites, and European settlers' romantic theorizings—the latter even more worthless if possible than the former. Mr. Wayland suspects a common origin with Zimbabwe, whose Bantu construction and medieval date he fully accepts on the latest published evidence (Caton-Thompson, 'The Zimbabwe Culture,' Oxford 1931). An origin for the stone-built Zimbabwe ruins from humbler equatorial prototypes was suggested by the present reviewer in 1930, and discoveries such as these in Uganda were inherent in that prognostication. Mr. Wayland however deems Biggo to be certainly younger than Zimbabwe: that may be so, but the Rhodesian ruins collectively and with certain modifications have been proved to cover a long range in time—possibly eight or nine centuries—and the later ones may confidently be dated to about A.D. 1700.

Speculation of age and origin is however useless until methodical excavations by experts are undertaken. In this connection a momentous footnote calls attention to a Uganda Protectorate Ordinance, twelve months old, promulgated, none too soon, to protect antiquities from ruination by well-meaning amateurs. With Mr. Wayland in office at Entebbe archaeologists will rest content that permits will be rigidly limited to trained and reputable excavators.

The past history of native Africa, a vast, practically untouched field of research, must, in the absence of literary record, be pieced together by purely archaeological method. Each ancient site rifled for "objects" by inquiring travellers or settlers; each cairn destroyed; each terrace levelled; each cave thoughtlessly dug; each pseudo-scientific expedition of adventurers, destroy irreparably a link—a paragraph of unwritten history—which in trained hands would have added its quota of exact information. If trained people are not available within our own generation the sites must wait; ill-founded history is worse than none; nothing is so urgent as the preservation of the evidence for those who can scrupulously use it.

Licensed adventurers bade fair to wreck the Rhodesian sites: that chapter in British colonization can best be atoned by an enlightened official policy respecting the antiquities in our charge throughout the world. To the Government of the Union of South Africa has gone the pioneer honour of creating, within the past few weeks, a National Bureau of Archaeology with wide powers to direct and control research.

REVIEWS

EUROPE

EAST ANGLIA. By R. H. MOTTRAM. *London: Chapman and Hall* 1933. $7\frac{1}{2} \times 5$ *inches;* xvi+358 *pages; illustrations.* 8*s* 6*d*

Mr. Mottram affirms in his Preface that "East Anglia is bounded by the sea, it must be east of the main railway and road to the north and most of all it is not London. This gives us something firm to stand on, . . ." But not really firm, for later on he says, "I dismiss Harwich, Newmarket and Cambridge, which belong to the Continent, the nation, and the world of learning. There is plenty left." True, but as far as we can see he only deals with Ely in Cambridgeshire, some parts of Suffolk and Essex, and with Lincolnshire not at all. Norfolk receives ample attention. His home city of Norwich is dealt with fully and provides by far the best part of the book, which unfortunately contains many archaeological and topographical, and some sociological, errors. The examples which follow are all taken from the first fifty-six pages of the book.

The exceptionally hard-pressed agriculturists of the area, the great majority of its population, might not confirm the author's phrase about "the comparative immunity of these parts in times of slump." He makes the entirely unfounded statement that the present Cathedral of Ely replaced "the wooden building burnt during the siege of the island by the Normans." And a little farther on: "the proper day to see Ely is a bright winter's one when the reeds are all dried biscuit colour, and it is plain how easy it was for determined men [Hereward's] who had been outlawed, to set fire to those rushes and burn the Norman's wooden causeway." Reeds and rushes do not grow on the highland of Ely, and the fenlands immediately around it are so intensively cultivated that they are found only in the few ditches that are not kept clean. Along the banks of the river they die down in the winter. Surely the fenlands are not as "sparse in population as any mountain ridge"? We are at a loss also to know why, in this respect, "The village names Waterbeach and Burnt Fen tell the tale," because the former was a village as far back as 1086 and Burnt Fen is not a village. "The water . . . at Ely is more than half Midland water." It is not. The only water that passes Ely city is that of the Cam and its little tributaries. One is hardly "liable to kick a neolithic implement at any step you take" in Breckland. The great majority of artifacts to be found there probably belong to the Bronze Age.

Such errors are no doubt due to the fact that the author does not know thoroughly either the country, places, people, history, or pre-history of the area. In fairness however to Mr. Mottram we must remember that, as a rule, it takes nearly a lifetime to write the history of even a single parish correctly. Uncritical readers will enjoy a great number of the anecdotes and reminiscences which Mr. Mottram recounts so vividly. G. E. F.

A SAUNTERER IN SUSSEX. By A. A. EVANS. *London: Methuen & Co* 1935. $7\frac{1}{2} \times 5$ *inches;* x+240 *pages; illustrations.* 7*s* 6*d*

There is a spate of books on the countryside, many of them marred by preciosity and superlatives. This book is different from the many. Mr. Evans was recently 'On Foot in Sussex,' and now he is a saunterer there. Few know more of the remote places in this county "so much exposed to authors," and few see so much in a single field as he. Writers like our author who can use trained powers of

observation quietly and restfully, and induce others to do likewise, are a genuine national asset in these days of restlessness and speed. When therefore Mr. Evans saunters in Sussex, sits on a stile for an hour to see and make notes, and thereafter writes with a humble mind and in simple language, he deserves the wide and appreciative audience he will probably get. No need to say where he goes or what he talks about: any one who goes with him will find him a delightful companion.

S. E. W.

THE BOTANIST IN IRELAND. By ROBERT LLOYD PRAEGER. *Dublin: Hodges, Figgis & Co.* 1934. $7\frac{1}{2} \times 5$ *inches;* xii + 588 *"pages"; illustrations and maps.* 12*s* 6*d*

The flora of a country is usually dealt with by setting out the species in their taxonomic order and indicating under each its characters, distribution, and such other matter as the author desires to include. Dr. Lloyd Praeger has reversed the process. He has adopted a topographical arrangement and takes the student, as it were, on a grand tour of Ireland, telling him what plants of interest he may expect to see during his progress. As the author points out, there are disadvantages in this method; but these are more than offset by its convenience both to the botanical traveller who wishes to see rare and interesting plants in their natural state, and to the ecologist who wants a conspectus of the various plant communities. Adequate floras of Ireland are in existence for those who wish to study the material in this form; but this handy volume occupies a place of its own and fills a gap in the literature. The book embodies in a condensed form the conclusions of half a century's field-work spread over the whole face of the country, and there can be but few who know the country and its plants as well as the present author.

The Irish flora is not so extensive or varied as that of Britain, but what it lacks in numbers it makes up in interest. Insularity is inevitably a limiting factor, but it produces a number of attractive problems the solution of which is of high importance to our understanding of distributional and evolutionary processes. Ireland is no exception to this rule. Its peculiar position in relation to the land mass of Europe, the varied nature of its geology and the warmth and humidity of its climate combine to produce for the phytogeographer some remarkably fascinating problems.

Before proceeding on his tour of the country, the author summarizes the geological, topographical, and climatic factors in their relation to the plant carpet; and he does not neglect the considerable changes produced by human influence. The sharp controversy that has raged around the part played by glaciation in the reduction or extermination of the flora and fauna is briefly and clearly set out with full references to the literature. The main topographical part of the book suggests centres where the visitor may stay and from which he may most conveniently visit the interesting features of the district. This is followed by an up-to-date census in terms of the forty Watsonian vice-counties which enables the student of distribution to plot the map of any species. There is an index of forty-eight pages; and the book is illustrated by a number of beautiful photographs and some useful maps. The method of numbering some of the pages by their paragraph numbers only and others as consecutive pages, though it has advantages where so many cross-references are necessary, is not altogether comfortable. Though not meant for continuous reading, this book can be confidently recommended as a good companion to the botanist visiting Ireland.

C. D.

PARIS: la ville et sa banlieue. By ALBERT DEMANGEON. (Monographies Départementales. Edited by R. BLANCHARD and D. FAUCHER.) *Paris: Bourrelier et Cie.* [1934]. 9×7 *inches;* 60 *pages; illustrations and maps.* 10 *fr*

M. Albert Demangeon, in his study 'Paris: la ville et sa banlieue,' treats his subject in a precise and analytical manner. The work is exhaustive in its scope and of great interest to the geographer, who is peculiarly fitted to appreciate the balanced treatment of the various aspects of the subject presented in the monograph. M. Demangeon first discusses the component parts of the Parisian landscape, viewed as the setting of the huge tentacle-like conurbation—as much the work of man as the result of geographical advantages. An analysis of the site and geographical position follows, and the growth of the present population is traced from its earliest beginnings. Paris now ranks among the nine towns of the world with a population of more than 2,000,000: in 1931 the figure was 2,891,000 (London—4,386,000), and for Greater Paris 5,900,000 (Greater London—8,203,000). The various functions of the city—administrative, industrial, commercial—are then discussed in detail. There follows an excellent description of the various means of transport, and of their relative merits, and a most useful summary of the trade returns of the port.

The influence of navigable waterways is shown in the type and density of the buildings and population on the lands adjoining. The author then examines the sources of the city's water, food, light, heat, and power, and deals with the organization of the local transport services. In the detailed description which follows of the regions within the conurbation, M. Demangeon recognizes their independent economic and administrative life, but stresses the entity of Paris in the words, "Dans le département de la Seine, tout gravite autour de la Ville de Paris; tout vit d'elle et pour elle." He concludes by viewing the conurbation from the town-planner's point of view, and shows how unplanned growth and the engulfment of villages and towns, with their separate, individual life, have led to the failure of the whole city to organize the best public and social services. His last paragraph strikes a warning note. The Parisian conurbation forms one-eighth of the population of France. Will it continue to grow, is it good that it should grow, is it good that it should continue to engulf the rural populations? Will it be possible to create good conditions for housing, sanitation, and work? Will work be found, and how will men live? He concludes, "N'y a-t-il pas risque qu'un jour cette grosse tête soit trop lourde pour l'équilibre du pays?"

The monograph is exceedingly well illustrated with fifty-eight maps, diagrams and photographs, and is an excellent production at a low price, but the value of the work to the student would have been enhanced had the author given the sources of his information. D. K. S.

ASIA

TURKESTAN SOLO: One Woman's Expedition from the Tien Shan to the Kizil Kum. By ELLA K. MAILLART. Translated from the French by JOHN RODKER. *London: Putnam* 1934. 9×5½ *inches;* xii+308 *pages; illustrations and maps.* 10*s* 6*d*

A good book, well illustrated, and nicely produced. In translation it inevitably loses some of its freshness, and probably does not do full justice to the authoress's powers. Using it however in conjunction with Bosworth Goldman's 'Red Road through Asia' the student of New Russia in Old Asia will get a very fair idea of what is going on at the present day over a very wide expanse of that continent—from the Arctic Ocean to the Tien Shan, from the Caspian to the Yenisei.

Mlle Ella Maillart went out to experience the rough side of travel; to tramp

or to ride by camel or by cart: no matter what means she had to use, so long as she achieved her goal. She evidently preferred the hard to the soft, and accepted fatigues and discomforts with a fortitude and disregard that would be unintelligible had we not known beforehand that she was an athlete of international repute! She was determined to go East, being bitten with a great desire to live the life of the nomads of High Asia, and in spite of many restrictions and obstructions, she got there. The difficulties of travel in U.S.S.R. are certainly not less than they were a quarter of a century ago. But nothing daunted Mlle Maillart. She pushed her way past every obstacle, sailed serenely over all the senseless officialdom, and finally embarked for Innermost Asia. Her road thither was by the old route from Moscow *via* Orenburg to Tashkent, branching off at Aris on to the newer Turk–Sib railway, which eventually brought the party (she had four companions on this part of the journey) to Frunze, formerly Pishpek. From this point they had the use of motor transport to the shores of Issik Köl, and a boat took them across that lovely alpine lake, which inevitably reminded the writer of her own Lake Leman on a giant scale. This landed them at Kara Kol, a name which successfully hides its identity, for it is no other than the memorial to one of the greatest of Russian travellers, the pioneer of Central Asiatic exploration—the renowned Prjevalsky.

At Kara Kol the party outfitted their caravan of horses and rode southwards over the Tereskei range to the head waters of the Narin, which is the very source of the Jaxartes, or Sir Darya. Here they fell in with their desired hosts, the true mountain Kirghiz, and they lived the life of the Yurt with them. In many ways this is the most interesting part of their journey, for few have seen the western slopes of Khan Tengri; and no Englishman is known to have been in the Upper Narin except Cobbold and the present reviewer. The party wandered from one encampment to another until finally they reached the southern passes leading down into Chinese Turkistan—"the water that runs at our feet will die away in the sands of China"; this had the effect of creating a wanderlust in Mlle Maillart which drove her back to Alma Ata, the present capital of Kirghizia, in hopes of obtaining a visa to allow her to enter China. The visa was not forthcoming, so she set her face westwards towards the legendary cities of Turkistan: Samarkand, Bukhara, and Khiva. From now onwards she was alone, "a vagabond in Turkestan." There follows a very forcible and vivid impression of Russian Turkistan as it is to-day; Tashkent, where the Ancient East is rapidly becoming Westernized, and the Moslem community is being turned into good proletariats; Samarkand, still aglow with its treasures of coloured mosque and minaret; and Bukhara, now alas! "the fallen," her glory having departed, for "it is only cotton that counts."

At Samarkand the writer came in for the State trial of some Basmachi revolutionaries, really Nationalists gone bandit, "the inevitable reaction to the anti-Moslem programme of the Soviet leaders." We are given a very good account of the whole revolutionary movement in Russian Central Asia which followed on the general mobilization during the Great War; a pitiable story, which, it is estimated, cost as many lives as did the original Russian conquest of those regions: those who know the story of that protracted campaign will appreciate the full meaning of the estimate. At Bukhara, against advice, the author determined to go to Khiva, and being too short of money to go by air (as you can do now, twice a week from Charjui) she boarded a steamer on the Oxus. The Oxus is not too well known, and as for Khiva and its environment, it must have satisfied even her craving for the little-known and out-of-the-way. Here was indeed a dead-end, from which she found it quite difficult to extract herself. If she had come to seek adventure she found it, for she was caught by fast-

approaching winter in what must be one of the most inaccessible places in the world. With the Aral Sea freezing up, and her retreat cut off, she had no option but to face a 300-mile trek by camel across the arid wastes which extend from the Oxus to the Sir Darya. The reviewer once spent the month of January in the middle of this very Kizil Kum and he can vouch that a winter's crossing is no joke.

The chief interest aroused by this book lies in the phenomenal insight which its writer exhibits when dealing with the very varied types of people whom she met; and they were indeed a mixed crew. Whether it was the independent-minded Kirghiz of the mountain plateaux, the still half-liberated Moslems of the great bazaar cities of the plains, or the motley array she was accustomed to share food and sleeping accommodation with at the "bases" of the Society of Proletarian Tourists, she seemed able both to grasp the mentality of each of them and to record her reactions to them. The whole volume is stocked with interesting anecdotes, contains much valuable information, and includes some of the most pathetic stories that we have ever read. The illustrations are a fine advertisement for the modern miniature camera, the Leica enlargements being as good as anything we have yet seen in book illustration. Two sketch-maps illustrating the general itinerary and the Tien Shan interlude occupy the front and back end-papers; there is also a good map showing the Oxus—Aral—Sir Darya region, to accompany the latter part of the journey. D. C.

ALEXANDERS KAMPF GEGEN POROS: ein Beitrag zur indischen Geschichte. By BERNHARD BRELOER. (Bonner Orientalistische Studien. Edited by P. KAHLE and W. KIRFEL. Heft 3.) *Stuttgart: W. Kohlhammer* 1933. $9\frac{1}{2} \times 6\frac{1}{2}$ *inches;* xii+208 *pages; illustrations, map, and plans. M.*14

This is a very thorough examination of the literary and topographical evidence for the long-disputed battlefield on the Hydaspes. Dr. Breloer states a strong and ingenious case for the Jhelum site, and illustrates his argument with some impressive photographs. As his essay was completed before he became acquainted with Sir Aurel Stein's re-statement of the arguments for the alternative Jalâlpur site, in *Geogr. J.*, vol. 80, 1932, pp. 31–46, he has added an appendix dealing with its principal points, challenging its conclusions, and especially its assumption of topographical changes since Alexander's times.

It should be noted that Dr. Breloer's treatment of the literary sources is itself a crucial instance for his general hypothesis that whereas Curtius's method is to state military motives and describe results, Arrian, with more direct access to documents, bases his narrative on original marching orders, and only sometimes supplements these by his own summary narrative of the fulfilment of them. Compared from this point of view, the tactics of the battle on the Hydaspes repeat those of the fight for the Susian Gates, and—it may be added—of Alexander's handling of his forces in general. That the narrative, as Dr. Breloer reconstructs it by purely literary criticism, so fully accords with the topography of the Jhelum battlefield, is certainly positive gain to the history of the Indian campaign. J. L. M.

INDO-CHINA: a Sportsman's Opportunity. By ARCHIBALD HARRISON. *Privately printed at The Mayflower Press, Plymouth* 1933. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* 158 *pages; illustrations*

This little book is an account of a big-game shooting trip in French Indo-China during the autumn of 1917, left by an American sportsman who died in 1928, and now privately printed by his relatives as a tribute to his memory. The scene of the adventures recorded was the then newly constituted Game Reserve known

as Lang Bian in the State of Annam. Tiger, the Indian Bison or Gaur, and Wild Cattle or Bantin were the destined quarry, and though many other varieties of game were seen they were not pursued except occasionally for the pot. The writer, a big-game shooter of repute in many parts of the world, had with him a companion from Manila and a French officer of the Indo-China Forest Service: the last a gentleman of infinite resource to whose local knowledge, experience, and lively humour the success of the party was in great measure due.

The book is divided into twelve short chapters, the first two introductory, the following five descriptive of the actual operations, and the remainder given to general remarks on the scenery, birds, beasts, and men of the district, and to useful hints for young shikaris on weapons, outfit, hygiene, and deportment. The tale is, on the whole, well told, the incidents of the chase, whether ending in triumph or, as frequently happened, in failure, being described with equal enthusiasm and gaiety. There are photographic illustrations, mostly of complacent hunters grouped about freshly killed game, which will interest sportsmen, though the presentation of the same dead animal in two different pictures, which occurs twice, may seem redundant. A tri-lingual vocabulary (not wholly correct) of some of the Indo-Chinese fauna appears on p. 31. There is no index.

W. A. G.

AFRICA

THE MAMMALS OF SOUTH WEST AFRICA: a Biological Account . . . By Captain G. C. SHORTRIDGE. *London: William Heinemann* 1934. $10\frac{1}{2} \times 7$ *inches;* Vol. I, xxvi+438 *pages;* Vol. II, x+439–780 *pages; illustrations and maps.* £2 2*s*

South West Africa, formerly German South West Africa and now a Mandated Province under the Union of South Africa, lies between the Kunene river on the north and the Orange river on the south. It is a very desolate region, especially along the coastal strip between the Atlantic and interior highlands. This rainless tract, varying from 15 to 85 miles in width, corresponds in climate to a similar strip of desert in north Chile. Inland the country is better watered and ranching is possible, and it is here that the German colonists settled.

Captain Shortridge is well qualified for his task, as during the last ten years he has made six collecting expeditions for the benefit of the Kaffrarian Museum at King Williams Town, of which he is Director, and for the Natural History Museum in London. The scientific results of these expeditions have been published in the Proceedings of the Zoological Society, and he has now gathered up all the results of his work and has added all the information available from other sources to form a complete account of the history, habits, and distribution of the mammals large and small of this extensive and unsettled land.

As is the case elsewhere, the larger animals are becoming increasingly rare. The Lion is steadily retreating before European settlement; the Elephants, abundant in the days of Andersen and Eriksson, the Swedish hunters and naturalists, are now probably not more than a thousand in number, confined to Kaokoveld in the north. The White Rhinoceros has been extinct for fifty years or more, and the Black is reduced to about fifty or sixty individuals. On the other hand some of the Antelopes are still fairly numerous; the beautiful Gemsbok or Oryx survives in most districts and the Springbok is abundant.

The greater part of the two volumes is taken up with the systematic history of the species, and our only criticism is the absence of descriptions and keys by which the identifications could be made, so that it will be difficult for the traveller or the resident to make use of this work for naming the animals, especially the smaller and less conspicuous species with which he may meet. The two volumes

are well provided with maps showing the distribution of all the more important forms and there is a large number of photographs, of which the most striking is a series taken from the air by Mr. J. Koester of herds of Wildebeest and other Antelopes galloping across the sandy plains. The publication of the work was made possible by a grant from funds provided by the Carnegie Corporation of New York, and the results are very satisfactory. W. L. S.

CENTRAL AND SOUTH AMERICA

GRUNDZÜGE DER GEOLOGIE UND LAGERSTÄTTENKUNDE CHILES. By J. BRÜGGEN. *Die Mathematisch-Naturwissenschaftliche Klasse der Heidelberger Akademie der Wissenschaft* 1934. $9\frac{1}{2} \times 6\frac{1}{2}$ *inches; 362 pages; illustrations and maps. M.30*

This book is a comprehensive account of what is known to date of the geology of Chile. The author has collected the material of others and supplemented it by his own field work extending over his twenty years' residence in Chile as a Professor at Santiago. Though the geology of the country has by now been attacked at numerous points, serious gaps still remain, the more so as Chileans themselves have hitherto contributed little to the scientific knowledge of their country in this direction. Dr. Brüggen has done a service in piecing together the material at hand and so compiling a useful work of reference, in which he treats not only of structural geology but also of such matters of general interest as the coastal forms, the evidences of glaciation, vulcanism, and seismology. As the title suggests, considerable attention is given to the mineral deposits, both proved and surmised, together with much detail of their modes of occurrence and economic exploitation.

In its physiography and geology as well as in its mineral resources Chile is an interesting country, and Dr. Brüggen's book throws the light of scientific interpretation on a number of the more striking features. The essential uniformity of structure throughout the 2500 miles from extreme north to extreme south is emphasized; the steep cliffs that so commonly form the shores are ascribed to extensive faulting which has also been responsible for the sharpness of the relief features at numerous places inland; the very broken southern coast owes its present fragmentary form mainly to repeated glaciation; the nitrate deposits in the north are apparently due to bacteria acting freely in a past age in the presence of ammonia gas given off by abundant guano deposits which formerly existed on the Coastal Range. On these and similar subjects Dr. Brüggen writes with authority, and his conclusions must serve as a basis for any further work that is done. The book is illustrated with a number of geological sketch-maps and sections in the text, mostly the results of personal investigation, and a few well-chosen photographs. The map of Chile appended is however on too small a scale to show many of the places mentioned. E. W. S.

PHYSICAL AND BIOLOGICAL GEOGRAPHY

ON THE EARTH-VORTEX, ECHELON FAULTS AND ALLIED PHENOMENA. By S. FUJIWHARA, T. TSUJIMURA, and S. KUSAMITSU. Sonderdruck aus Ergebnisse der kosmischen Physik, Band II, pp. 303–360. *Leipzig: Akademische Verlagsgesellschaft M.B.H.* 1934. $9\frac{1}{2} \times 6$ *inches; illustrations and diagrams*

From an examination of the observed displacements due to the great Tokyo earthquake of 1 September 1923 the authors conclude that the movement was similar to that in a vortex. But they go much farther. They draw a "vortical chain" from the Shetlands to Ben Macdhui; they recognize vortical forms in the

Alps, in the ranges of south-eastern Asia, and in the Malayan Archipelago. Giving free rein to their fancy they even see a giant vortex in the geological map of Russia. But they pay no attention either to geological history or to geological structure.

Since the authors draw their conclusions from an analogy with motions in a fluid there is some likeness between their ideas and those put forward by Schwinner ten or twelve years ago. But Schwinner supposed that the crust of the Earth is passive and that the primary movements take place in the magma beneath, the crustal movements being entirely secondary; and he did not seek for vortices upon the surface. P. L.

UM DAS GEOLOGISCHE WELTBILD: Malleo et Mente. By ERICH HAARMANN. *Stuttgart: Ferdinand Enke* 1935. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* xii+108 *pages; illustrations and diagrams. M.*5.80

The greater part of this booklet is occupied by general remarks on the importance of distinguishing between facts and hypotheses, the use and abuse of theories, and kindred matters, slightly tinged perhaps by the reception accorded to the author's own *Oszillationstheorie*. There is no serious attempt to discuss or even to expound this theory, but the author finds confirmation for some of his ideas in the system of clefts which form so marked a feature of Fennoscandia. P. L.

INTRODUCTION TO THE REPORTS FROM THE CARLSBERG Foundation's Oceanographical Expedition Round the World 1928–30. Published by the CARLSBERG FOUNDATION. *London: Oxford University Press* 1934. $12 \times 9\frac{1}{2}$ *inches;* 130 *pages; illustrations and maps.* 16*s*

The larva of the common European eel was found outside the Mediterranean for the first time in 1904, when Dr. Johannes Schmidt obtained it in the Atlantic Ocean west of the Faeroe Islands, a discovery which led up to the great series of investigations which he continued until his death in 1933 and upon which above all his fame is founded. His expeditions of 1920–1922 showed that the European and American eels both spawn in a region not far from the West Indies, and that owing to a difference between their rates of development their larvae are carried by the currents to the European and American coasts respectively. Following on this he undertook a laboratory examination of eels from all parts of the world and found that two species occur in the Atlantic, twelve in the Pacific, and six in the Indian Oceans. He then drew up a programme for a voyage of investigation round the world and carried it out with the help of the Carlsberg Foundation, which provided the money, and of the Danish Government, which lent the research ship *Dana II* and part of the scientific staff.

The volume under review gives a sketch of Schmidt's investigations, a very condensed account of the voyage, chiefly in the form of tables, a full table of the 667 stations, and the complete report on the echo-soundings by Lieutenant Sv. Greve. The 8181 soundings reported here were all made for charting; many thousands of others were also made in the course of working the oceanographical gear. The machine used was the Atlas Echo Sounder Type II, which gave little trouble; the makers estimate the error due to the gear alone as $\pm 0{\cdot}5$ per cent. Deep soundings depend upon eye and ear and the personal equation of the observer affects the results. In an extreme case quoted the maximum difference between nine observers was 75 metres in a depth of 2755 metres. Few control soundings with the wire were made and the results were not conclusive; it seems probable that the echo soundings were the more accurate. The soundings in the table are all calculated for a uniform velocity of sound of 1500 metres per second. D. J. M.

ECONOMICAL AND HISTORICAL GEOGRAPHY

DIE ERDKARTE DER URBIBEL, mit einem Anhang über Tartessos und die Etruskerfrage. By ALBERT HERRMANN. *Braunschweig: Georg Westermann* 1931. 10×7 *inches;* 204 *pages; illustration and maps*

The Hebrew 'Book of Jubilees' has been transmitted only in an Ethiopic and a Latin translation. It gives a romantic and tendentious version of incidents recorded also in Genesis and Exodus, and it has been commonly ascribed, on internal evidence (its "prophecies" about Maccabaean events), to the generation of John Hyrcanus (135–105 B.C.). Dr. Herrmann attempts "to solve an old problem in a new way." His contention is that the Maccabaean allusions and the chronological reckoning by "jubilees" are due to an "editor"; that the substance of the document (apart from earlier editings under Josiah) belongs to the reign of Solomon; and that its geographical allusions, and especially the "table of nations" which takes the place of the pedigrees in Genesis x, are contemporary beliefs about principal peoples and tribes, and their regional distribution. The source of this geographical lore was in turn (he thinks) a Phoenician *map*—a real piece of cartography, afterwards lost (p. 143)—adapted to Hebrew use by making Jerusalem the world's centre instead of Tyre. These conclusions he finds supported by the geography of the Samaritan 'Book of Secrets' (Asatir).

Even supposing Dr. Herrmann's literary criticisms to be sound, the range of geographical knowledge which he ascribes to tenth-century Phoenicians and Hebrews is remarkable. Not only the whole extent of the Mediterranean, and the Aegean, Pontus, and Maeotis (*Méat*), are exhibited, but Europe has its three southern peninsulas, ascribed respectively to Mesech, Tubal, and Aferag (=Thrace). North of Pontus lie Madai, Magog, Gog, and Gomer (=Cimmerians), with the river Don (*Tina*) and a tributary of it rising in Caucasus. Eastward, on the other hand, there is no knowledge of the Persian Gulf; the Euphrates flows eastward after leaving the "Mountains of Assur," and has a large tributary ("Pison" of Genesis x) out of Arabia; the Red Sea is given almost its actual shape and relative size; and a sea called *Atel* separates *Phut* (=Libya) from *Canaan* (in Mauretania),—here identified with the Tunisian Shotts and the original "Atlantic." That north-western Africa should have been regarded as "Canaanite" already, a century or more before the foundation of Carthage, and that "Canaan" should have disappeared from the maps of Syria seven centuries before Alexander's destruction of Tyre, are the most surprising of all these reconstructions. But here Dr. Herrmann is on his own ground, for not only did he argue in a previous book that the Trojan War occurred in South Tunis, but he persuaded the Prussian Ministry of Education to endow two expeditions to substantiate this and other "Tritonian" theories. For in his Tritonian lake-land lay not only Homer's Troy but the Tarshish of Hiram; and a lengthy appendix (pp. 145–186) develops an *obiter dictum* of Stuhlmann into a clue for the reinterpretation of the *Ora maritima* of Avienus and other classical authorities in this sense. This in turn leads to the derivation of Etruscan culture from that of this Tritonian "Tartessus." As Dr. Herrmann observes (p. 186), if all this is accepted, it involves a complete revision of our ideas on other subjects too; not least on the value of Greek writers on geography, whose "transpositions of names" he repeatedly criticizes when he needs those names elsewhere, but whose notions so clearly determine those of the 'Book of Jubilees' as to leave undisturbed our impression that its geography, like everything else about it, is Maccabaean, not Tyrian or Solomonic. J. L. M.

GENERAL

GOOD MORNING AND GOOD NIGHT. By The Ranee MARGARET OF SARAWAK. *London: Constable & Co.* 1934. 9×5½ *inches;* xii+308 *pages; portraits.* 15*s*

The Ranee of Sarawak has a sense of humour combined with an original turn of mind which makes one feel that anything she wrote would be fascinating. In England, at the age of twenty, she met and married Charles Brooke, Rajah of Sarawak, but since most of her childhood had been spent in France she was actually more French than English, with the French demonstrativeness and lack of reserve which made her life with the self-contained natives and the rigid Charles Brooke seem all the more strange. She was constantly making mistakes in etiquette and her accounts of them are most amusing. Her descriptions of the natives and the country itself are vivid.

She pays tribute to the way in which the Rajah dealt with his people, his tact and courage. From the moment she met him she knew that Sarawak was his chief interest. All his life he continued to put its welfare and prosperity before all else, even herself. Now, looking back in the peaceful evening of a life which has already lasted eighty-five years, the authoress must feel that she married a country rather than a man, but since she grew to love it she must be glad that she gave it three sons in whose keeping it would remain secure. P. M. S.

THROUGH ATLANTIC CLOUDS: the history of Atlantic Flight. By CLIFFORD COLLINSON and Captain F. MCDERMOTT. *London: Hutchinson & Co.* 1934. 9½×6 *inches;* 288 *pages; illustrations and map.* 18*s*

The courage, determination, and light-heartedness of those who have taken part in the conquest of the air have always been a source of delight and wonder. In 'Through Atlantic Clouds' the true stories of the pioneer Atlantic flights convince one that probably no other enterprise has ever called for these qualities to so great an extent. Messrs. Collinson and McDermott have collected, for the first time in one volume, the true records of all the attempts, successful and unsuccessful, to cross the Atlantic by air. The writing is straightforward and unaffected, and intended for the general public rather than for the technician, although for those who like data in a more concise form there is an appendix at the end. Though these flights are comparatively recent, most people have already forgotten many of them. Few indeed will know the details of more than one or two of the outstanding successes, such as those achieved by Alcock and Brown, by Lindbergh, and by Miss Earhart.

Considering the future importance to Great Britain of air communications, the book will interest everybody who is at all air-minded. It is also valuable as an historical record. V. B.

DE ENGELSCHE GEOGRAPHIE IN DE 20STE EEUW. By WILHELMINA JOHANNA HUENDER. *Utrecht: J. Van Boekhoven* (1934). 9½×6½ *inches;* x+184 *pages*

Two or three years ago a Dutch lady student came over to this country to hear from their own lips an exposition of the views of English geographers upon the content and method of their subject. The results of these investigations were embodied in a thesis for which the author was awarded the degree of Doctor of Letters by the University of Utrecht.

Dr. Huender sets her stage by summarizing from secondary sources the progress of geography in England from the time of Alfred the Great. This

chapter is followed by a succinct account of the work of the pioneers of the modern geographical movement, Mackinder, Mill, Scott Keltie, Chisholm, Herbertson, and the late Dr. Newbigin. She then breaks new ground with the post-war geographers, and selects a dozen of these (25 per cent. from the London School of Economics) for intensive study, as presumably representative of current English geographical thought. The ideas of these geographers are compared among themselves, and are measured against the concept of geography accepted in Utrecht, namely, "a science which, by means of the landscape, takes the social group in its efforts towards general welfare, and its structure as restricted by its habitat, for its field of study" (quoted from the English Synopsis, p. 159).

It is not easy to decide whether the space devoted to particular geographers among the selected dozen is in proportion to Dr. Huender's view of their importance or to their readiness to explain themselves to her at length. Professor Fleure, Dr. Stamp, Dr. Unstead, and Professor Roxby, in the order given are each allotted over three thousand words. Dr. Bryan stands in the second class with over two thousand words, while Professors Fawcett and Ogilvie tie with just over one thousand words apiece. The ideas of Miss Hosgood, Mrs. Ormsby, Professor Rodwell Jones, Mrs. Wright, and Mr. R. E. Dickinson are dismissed in a few hundred words in each case.

Dr. Huender found the results of her inquiry very puzzling indeed, for it appeared to be case of *tot homines, tot sententiae.* She was obliged to fall back on an examination of the English character, as delineated in 'Sir Roger de Coverley,' and in the works of Mrs. Virginia Woolf and H. W. Nevinson. Attracted by its promising and seemingly relevant title, she also read Renier's brochure, 'The English, are they Human?' Here she found the clue to geographical confusion, namely, "the dislike of every system of thought-theories" which is inherent in our race.

Dr. Huender's final conclusion was consoling to the present reviewer, who was at first rather chap-fallen at finding herself excluded from the category of the dozen English geographers worthy of consideration. This conclusion, quoted from the English Synopsis (p. 161), is as follows: "The attempts of English geographers to arrive at a definition of geography . . . cannot be said to be a success. It is to be regretted however that while the achievements of British geographers . . . should deserve our greatest respect, they have not as yet led to a revision of the subject and method of geography. On the contrary, there is a distinct aversion on their part to theoretical ideas of this nature." The good-natured dozen are rather ill rewarded! E. G. R. T.

THE MONTHLY RECORD

A NEW GEOGRAPHICAL MAGAZINE

Fellows of the Society will be interested to hear that a new geographical publication is about to make its appearance entitled *The Geographical Magazine*. Among its Founders are included men distinguished for public service in many walks of life, and it has been planned in consultation with, and for objects which merit the approval and interest of, the Royal Geographical Society. Upon the domain of the latter it will in no way encroach, but it has long been felt that there was room for a publication which could treat the spacious canvas of Geography with a lighter and more colourful brush than it is possible for a scientific Society to employ.

It is understood that the first number of the new magazine will appear in the course of the present month, under the editorship of Mr. Michael Huxley, a scion of the family so distinguished in science and literature; and the infant starts on its career with the cordial wishes of the President and Council for its success.

P. Z. C.

THE NEW BUILDING OF THE SCOTT POLAR RESEARCH INSTITUTE

A good deal of space in the January 1935 issue of *The Polar Record* is occupied by an account of the opening on 16 November 1934 of the new building of the Scott Polar Research Institute in Lensfield Road, Cambridge. Four pages of plates supplement the description of Sir Herbert Baker's architecture, Lady Hilton Young's sculpture, and Mr. Macdonald Gill's cartographical decorations for the Arctic and Antarctic Domes which form a striking feature of the vestibule. Each dome is surrounded by the names of great explorers, which, it is explained, "do not constitute 'a roll of honour' except in a cartographic sense: each sector of the map has opposite to it the names of the men chiefly responsible for discoveries in that region." The ground floor is occupied principally by a museum of polar equipment, including articles of both practical and historical interest. The first floor contains the library, the map room, and two research rooms; the second floor is intended to house the Institute's already large collection of photographs, a long gallery having been designed for the display of these and of water-colours by Dr. E. A. Wilson. Over Lady Hilton Young's bust of Captain Scott above the front door there stands the inscription QUAESIVIT ARCANA POLI VIDET DEI, which the Institute owes to Sir Herbert Fisher, Warden of New College, Oxford.

The value of the work done by the Institute and of its *Record* is well known to readers of this *Journal;* it is clearly and forcefully expressed in Mr. Baldwin's address to the distinguished gathering that filled the Senate House for the opening ceremony, which is here reproduced almost in full. (It is a pity that the date of the opening is not given in this number of *The Polar Record*, just where the future student would expect to find it.) We may congratulate the Scott Polar Research Institute on possessing at last a worthy home for its collections and its ever-widening labours.

MOVEMENTS OF BRITISH COASTLINE

In a short illustrated paper in *Antiquity* for September 1934 entitled "Some Observations on Recent Geological Movements of the British Coastline," Professor O. T. Jones deals with upward and downward movements of the coastline, as indicated by both raised beaches and drowned valleys or submerged land

surfaces, often within a short distance of each other. He also considers the criteria, physical or stratigraphical, faunal or floral, and cultural, for determining the age of movements and correlating the movements in different parts of the coast. His main purpose however is to show the fallacy of regarding such a feature as a raised beach, standing approximately at 25 feet above the sea, which is common both in the north and south of the British Isles, as proof of uniform upward movement, since it is now certain that the beaches of different localities belong to different geological ages. At Selsey Bill a beach raised some 15 feet above the sea stretching eastward to Brighton is of much later date than one of similar height in the Gower Peninsula, South Wales, whereas farther inland there is another beach about 100 feet higher of the same age as that in Gower.

The history of movements in the north of Britain is very different from that in the south. In Scotland there are three conspicuous shelves or platforms generally referred to as the 25-foot, the 50-foot, and 100-foot raised beaches. A careful survey might show that a 50-foot beach in the south-west of Scotland corresponded to a 100-foot beach farther north. It is believed that the 50-foot and 100-foot beaches were deposited while glaciers occupied the upper ends of Highland valleys. The 25-foot beach which is also well seen on the Antrim coast of Ireland is definitely post-glacial since the shelf on which it rests is covered in glacial clays. In the Gower Peninsula, on the other hand, remains of *Elephas antiquus* and other mammals in a cave adjoining a 25-foot raised beach point to pre-glacial age.

In Antrim there is found important evidence regarding the age of the 25-foot raised beach of Northern Britain. At Larne the beach has yielded large numbers of stone axes referred to the Neolithic period, but in Belfast Lough a submerged bed of peat is overlain by estuarine deposits said to be of the same age as the Larne gravels. This must mean that during the formation of the Larne beach deposits depression was in progress which resulted in a pre-existing land surface being carried well below sea-level. But elevation of the coastline has subsequently formed the raised Larne beach and the peat bed is less deeply submerged than formerly.

If the submerged peat in Belfast Lough can be equated with the earliest peat beds in South Britain as found in Devon and Glamorgan, it would appear that since these beds were formed the earlier movement in both regions was one of depression, the later movement an uplift in the north but a continued depression in the south. Hence there is no doubt that the latest movement recorded on the British coastline affected different parts of the coast in varying degrees and must be referred to an actual movement of the land, not affecting the level of the ocean as a whole.

WELSH RIVERS AND THE THAMES

In *Science Progress* for July 1934 Mr. Philip Lake gives an interesting interpretation of the river system of Wales in relation to a former connection with the Thames. He begins by representing the mountain mass of Wales as the south-eastern remnant of a sunken dome whose longer axis runs approximately from south-west to north-east through Snowdon. With reference to this the drainage system of the country, which at first sight looks extremely complicated on the map, is found to resolve itself into two groups of river valleys, the radial directed down the dome, and the transverse directed along the flanks of the dome always at right angles to the radial direction at the same point. The transverse valleys are usually free from irregular bends and receive many more tributaries from their inner side (that is the side towards the Snowdon axis) than from their outer, whereas the radial valleys are less steady in direction and receive tributaries

equally from both sides. Four major transverse valleys divide the dome or mountain mass of Wales into a number of strips: one runs from Portmadoc to the mouth of the Conway; another, containing Lake Bala, from Barmouth to the mouth of the Clwyd; a third, not crossing the whole width of the mountains, contains the Upper Severn; and a fourth, also incomplete, stretches from St. Bride's Bay along the valley of the Towy to Llandovery.

The fundamental distinction in hydrology between the two types of valley is this: the radial valleys are purely erosion valleys cut by the streams which occupy them and are in general quite independent of the geological structure of the ancient rocks in which they are cut; the transverse valleys, on the other hand, do not follow the general slope of the country through which they pass and their directions are closely related to its geological structure, being determined by faults, folds, and other lines of disturbance. So completely do the radial streams ignore the structure of the rocks over which they now flow that it is difficult to avoid the conclusion that their courses were determined before they reached these rocks: they must, in short, have originated upon a cover of more uniform composition. Many of them were deflected into the transverse streams which were formed at a later date.

Reviewing the geological evidence Mr. Lake considers it almost certain that the Cretaceous rocks once covered a considerable part, if not the whole, of the Welsh mountains. He points out that the westward rise of the chalk of the Chiltern Hills is enough to carry the base of the chalk over the top of Snowdon. No direct evidence however is left because the deposits were too soft to resist the glaciers of the Ice Age. The question then arises whether the radial rivers that once flowed over Cretaceous rocks in Wales continued in the same direction when they reached the English lowland or were intercepted by the lower Dee and lower Severn. In the former case some of them must have joined the Thames. A clue to the answer is suggested by the gaps, now dry but evidently cut by running water, which break the Cotswold scarp and lie at the head of several of the Cotswold tributaries of the Thames, including the Windrush, Evenlode, and Coln. Geologists generally agree that the Oolite beds which form the Cotswold range with the outlier of Bredon Hill formerly spread over the Trias deposits of the Severn plain. Streams, issuing from the Welsh hills, flowed across the Oolite beds now occupied by the Severn valley into and through the Cotswold scarp. Later, after the Oolite had worn away, a stream began to flow over the soft Triassic strata now uncovered into the Bristol Channel, and the transverse lower Severn valley was developed with deflection of the radial Welsh streams into it and truncation of the Cotswold tributaries of the Thames. The suggestion that the Thames once drew water from Wales has, it is pointed out, been made by previous writers, including W. M. Davis, but their geological explanations differ from that now advanced.

PHYSICAL GEOGRAPHY OF SYRIA

In recent years considerable work has been carried out by the French administration in Syria and Lebanon to appraise the natural resources of the mandated area. The region being largely dependent upon agriculture for the support of its population, it is natural that the results of these surveys should be assembled to elucidate the problem of water supply. A recently issued number of the *Revue de Géographie physique* (T. vi, fasc. 4, 1933), compiled with the assistance of the 'Haute Commissariat,' deals entirely with the hydrological "cycle" in Syria. Mons. L. Dubertret, chief of the Geological Section, gives a concise account of the topography, structure, and geology of the area, illustrated by a

geological map in colour on the scale of 1/M. This is followed by Mons. C. Combier's analysis of the climate, and, finally M. Dubertret correlates the varied factors in a discussion of the subterranean hydrology and the hydrography.

The character of the vast continental area, of Cretaceous sediments, homogeneous in structure, limited on the north-west by the Taurus and on the north-east by the mountains of Kurdistan, and the climatic influences, which rapidly pass from what is styled a "degenerate Mediterranean type" to the desert type of the east, restrict hydrographic activity and perennial streams to the fractured coastal belt. M. Dubertret however considers the territory to be relatively rich in water: the calcareous massifs—the fissured Jurassic of the coast, and the Miocene of the interior—form substantial reservoirs, and a great accumulation of water may be deduced from the steady flow, from year to year, of many springs after the end of the rainy season. Between Saida and Tyre there is artesian water to be tapped under the chalk, and in the interior drainage basin around Aleppo supplies may be obtained from the ancient hydrographic system, now buried. The inclusion of a bibliography of over eight hundred entries by Mons. A. Keller adds much to the value of this work as a summary of our present knowledge of the physical geography of Syria. There are also a number of excellent photographs.

PLACE-NAMES IN NEW ZEALAND

Under this title the first *Bulletin* issued by the Honorary Geographic Board (*Wellington* 1934: 48 *pages*) contains "Rules of Nomenclature and List of Names Approved, or Changed, or Expunged." It is compiled by Mr. Johannes C. Andersen, F.R.S.N.Z., the well-known authority on Polynesia, and shows every sign of very careful consideration. "The rules adopted by the Board for its guidance will give an idea of the procedure it is attempting to follow." Each rule is followed by an explanatory paragraph or two packed full of interesting and even surprising facts. Both European and Maori names present various problems too numerous to be detailed here. Some places have a choice between a European and a Maori name; the native form does not always win, for example in the case of Mercury Bay—Whitianga, where the residents voted heavily in favour of Mercury Bay, a name recalling the observation of the transit of Mercury by Captain Cook in 1769. Rule 9 reads: "The Board suggests that the initial letters of generic or descriptive parts of geographical names, when used in reports or other documents, should not be in capitals." It is therefore proposed to write such forms as "Cook strait," and even "Cookstrait" is considered possible; but the word Bay in Mercury Bay (the village) is not regarded as a descriptive term.

For pronunciation the Board has adopted the R.G.S. system, and Maori sounds are carefully explained. It is unfortunate that many New Zealanders mispronounce the Maori *ng*, which should be as in *singer*, not as in *finger*. There are no real diphthongs; in the pairs of vowels, of which every possible combination is found, each vowel is pronounced but without a pause between them. The language is largely made up of disyllables, each of which has a slight stress on the first half. In the list a name is broken up into its component parts by vertical bars, as A|tia|muri; in actual usage the name is written as one word, for by Rule 6 hyphens are to be avoided, though an acute accent is occasionally allowed, as in Tuamárino. Though all its principles may not meet with approval, the Board is to be congratulated on a useful and scholarly piece of work.

OBITUARY

MR. H. G. PONTING

Herbert G. Ponting, who died on 7 February 1935, aged sixty-four, joined Scott's Last Expedition in New Zealand. In his early days he had ranched and mined in California, and had been correspondent of *Harper's Weekly* in the Russo-Japanese War. He persuaded Scott that there was a great future for the cinematograph, and in 1910 this wanted good judgment. He was plunged into the thick of things by the narrow escape of the *Terra Nova* off Campbell Island, when a ship of some 500 tons was bailed out with three buckets; then into the wild beauty of the bergs with the seas dashing upon them, and the calm serenity of the pack. Those three weeks in the pack-ice gave him a chance which he took with both hands and characteristic enthusiasm.

The Antarctic is the most beautiful place in the world. For some fourteen months Ponting lived in and about our hut at Cape Evans and produced a record which, so far as photography allows, has enabled the world to share that beauty. It is a great pity that he did not go sledging, but he was taken to the edge of the Barrier at the start of the Polar journey, and there, on his film, you may still see Scott and Wilson starting from Safety Camp, and Bill turn round and wave farewell. He was a highly strung, emotional man, and almost passionate in his art: an example of what a specialist who does one job and one job only can produce on such an expedition. When he returned with the relief ship in 1912 his job was done: there would have been no object in his remaining for the last year.

"Ponco" became his name: to "pont," that is, to pose for your photograph to be taken, part of our local vocabulary. Some men hated it; others did not. The seamen without any ill-feeling considered him to be a Jonah: and when we were sledging we supposed that another Jonah would be found. Not a bit of it: a camera was quite enough, and when Scott or Bowers appeared to photograph the camp or the mountains, the ponies or the dogs, some one immediately cried "Blizzid"! They were generally right. He wrote one of the best poems in the *South Polar Times;* he gave us illustrated lectures which took us right out of our surroundings; and at intervals he added a few more hundred feet to that film which, when uncut, set a standard of beauty which has never been surpassed. For an hour or two you could be *in* the Antarctic watching the bergs and their ice-cliffs go by; the penguins play; the ship's bow fight the floes; could almost hear the pack sliding along her sides. You could see the steam clouds rise from Erebus: the big seals gnaw their way out of the sea while their little ones chased their tails: men, ponies, and dogs about their work. Among and about these men Ponting left a lasting record. He came to do a job, did it, and did it well. Here in these pictures is beauty linked to tragedy—one of the great tragedies—and the beauty is inconceivable for it is endless and runs through eternity.

APSLEY CHERRY-GARRARD

Eighth Evening Meeting, 4 March 1935. The President in the Chair

Elections: Harold Evelyn Talbot Agar; Donald C. Beatty; Miss Daisy Gertrude Bloom; Leonard Robert Dawson; Lieut. A. S. T. Godfrey, R.E.; John Sanders Hobbs; The Rt. Rev. Harold Ernest Lumsdale; John Keith McCarthy; Thomas Piercy Mills; Richard Perceval Bagnall-Oakeley; Hugh John Simpson; Harold William Tilman, M.C.; Frederick Toppin; William Watson

Paper: The Encroaching Sahara. By Professor E. P. Stebbing

Fifth Afternoon Meeting, 11 March 1935. The President in the Chair

Paper: An Inland Water Survey for Great Britain. By Dr. Bryson Cunningham

Ninth Evening Meeting, 18 March 1935. The President in the Chair

Elections: Lieut. C. C. Ll. Browne, R.A.; Alfred Ellison; C. W. A. Garland, B.SC.; Charles Henry Maxwell Knight; James Bedford Jeffries Osborne; Miss Amy Reilly; The Reverend A. C. Reynolds, A.K.C.; Captain C. R. Robbins, M.C., D.F.C.

Paper: Across the Coast Range of British Columbia. By Wing-Commander E. B. Beauman